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ABSTRACT

A series of experiments were conducted to determine what information readers use when they read to understand a story. The experiments examined both skilled adult readers and children beginning to read. Oral reading was used both because elementary school teachers frequently ask children to read aloud and because oral reading provides an indication of processing difficulty while the reader is reading. In most of the experiments, violations of different types of information--for example, a nonword, a misspelling, a semantically anomalous word, an ungrammatical word, or a factually inconsistent word--were introduced into common stories. The readers' oral productions were analyzed for disruptions around each violation on the theory that if there were disruptions, then the readers must have been attempting to comprehend the distorted information. Across the experiments it was found that (1) readers used some types of information to find words in their mental dictionaries and other types of information to comprehend sentence meanings; (2) children reading grade-appropriate stories were governed by the same reading comprehension processes as were skilled adult readers; and (3) readers adapted their reading processes to changes in the reading situation, such as when pronunciation or comprehension was emphasized, or when information was encoded differently (as in Polish and English). The pattern of results provided strong support for an interactive model of reading comprehension. (Author/FL)

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Text Comprehension Processes in Reading: Final Report

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Abstract

What information do readers use when they read to understand a story? The focus of the research reported here was to answer this question for skilled adult readers and for children learning to read. Oral reading was used to investigate the problem because elementary school teachers frequently ask children to read aloud and because oral reading provides an indication of processing difficulty while the reader is reading. In most of the experiments, violations of different types of information, for example, a nonword, a misspelling, a semantically anomalous word, an ungrammatical word, or a factually inconsistent word, were introduced into common stories. The readers' oral productions were analyzed for disruptions around each violation. If there were disruptions, then the readers must have been attempting to comprehend the distorted information. Across several experiments, readers used some types of information to find words in their mental dictionaries and other types of information to comprehend sentence meanings. Children reading grade-appropriate stories were governed by the same reading comprehension processes as were skilled adult readers. Readers adapted their reading processes to changes in the reading situation, such as when pronunciation or comprehension was emphasized, or when information was encoded differently, as in Polish and English. The pattern of results provided strong support for an interactive model of reading comprehension. Readers use multiple sources of information to understand texts sufficiently well to satisfy the immediate demands.

I. Introduction

What are the cognitive processes by which a representation of a text is constructed from print? How do children learning to read learn these processes? Providing answers to these two questions has driven the research project summarized in this report.

Properties of Reading Comprehension Models

Research on reading comprehension has focused increasingly on identifying processing components. There are at least three major processing components in language comprehension: lexical access, sentence comprehension, and discourse understanding. Lexical access involves locating a lexical item in the mental dictionary and selecting an appropriate meaning. Bottom-up perceptual information, auditory and visual, is important for identifying a word; however, top-down contextual information, syntactic, semantic, textual, thematic, and factual, also influence lexical access. In sentence comprehension, the listener or reader integrates the word meanings into a representation for the entire sentence. Syntactic structure is available to guide the integration, but how active a role it plays is not clear. In discourse understanding, the listener/reader organizes the representations of individual sentences into discourse structures corresponding to the schemata of conversations, lectures, stories, and nonfiction prose. As sentences are comprehended, a discourse structure is constructed that is updated as additional information is received.

While numerous models of language comprehension processes have been proposed, they fall into two fundamental classes--interpretive models and interactive models (Danks & Glucksberg, 1980). Both classes of models assume that comprehension is the result of processing components that transform the input information in various ways to construct a meaning representation of the discourse. The two classes of models differ in the relations among the processing components. There are five properties (four of which were discussed in Danks, 1978) that differentiate the model classes.

(a) Directionality of processing. Most models of language comprehension have assumed a bottom-up direction of processing, but more recent models have recognized the importance of top-down processing as well. In bottom-up processing, the input signal (speech or print) is processed first, followed by lexical access (word recognition), sentence comprehension, and discourse understanding. In top-down processing, the more abstract processing components exert an influence on the lower-level components, typically through some sort of predictive, synthetic, or expectancy mechanism.

(b) Temporal organization. Temporal organization of processing components refers to whether the components are ordered serially or whether they operate in parallel. If the processing components operate in sequence, either bottom-up or top-down, then the temporal organization is serial. Serial processing has been the more common assumption for comprehension models. With parallel processing, the alternative, all processing components, or at least several of them, operate simultaneously.

(c) Dependency among components. Dependency among components refers to whether each component proceeds to analyze its input without being influenced by any other components (autonomous processing) or whether components influence each other directly by exchanging information during processing (interactive processing). In practice it is easier to design serial models to be autonomous and parallel models to be interactive, but it is possible to conceive models of the opposite sort.

(d) Flexibility of organization. A rigid processing model follows the same order of processing components each time an input is encountered. Flexible processing, in contrast, permits the total process to be altered to meet special input conditions or to satisfy output requirements such as the purpose for reading. Rigid models have a single set of processing components that apply in a fixed order, whereas flexible models vary their processing structure to fit the situation.

(e) Meaning representation. Some models yield only the literal meaning of the utterance or text as output; others yield directly the intended meaning conveyed by the speech or print. Those models that stop at the literal meaning generally view extraction of the conveyed meaning as an additional problem to be solved after the literal meaning has been extracted and found not to make sense in the situation. Most models that deliver conveyed meaning do so as an integral part of the comprehension process, often without even identifying the literal meaning.

While these properties are not completely independent, especially as they are organized into an actual model, decisions on the properties tend to be correlated. A modal version of the interpretive model is bottom-up, serial, autonomous, rigid, and yields a literal meaning representation. A typical interactive model is both bottom-up and top-down, parallel, interactive, flexible, and produces the intended or conveyed meaning.

Lying behind these two classes of models is an implicit emphasis on representations or on processes (Danks & Glucksberg, 1980). Interpretive models are more concerned with the form and content of the successive mental representations with particular emphasis on the final representation. Hence, studies from an interpretive point of view tend to assess representations using various memory probes. These probes usually are introduced after processing is complete. There is relatively less interest, theoretically or empirically, in the process of how the representation was formed. The interactive models, in contrast, emphasize the process, that is, to specify the manipulations performed on the information that yield the representation. The nature of the representations is important, but since a representation might have been constructed from a variety of different processes, the emphasis is on how the representation was constructed. Most of the experiments from an interactive perspective tend to assess what is happening during the course of processing. Such measures are called "on line" since they are contemporaneous with processing.

Conceptually, an interactive orientation has driven the empirical work covered in this report. It is not possible to formulate a precise test between the two classes of models, but evidence can be accumulated

for various properties. In general, the results from the studies reported here have been interpreted more completely within the framework of an interactive model, but neither model can be accepted completely.

Factors Influencing Processing

Since the research reported here was conducted from an interactive perspective, it has been concerned more with process than with representations. The problem is, of course, how to investigate a process when it is constantly flowing and fluctuating. The solution adopted here was to assess the process in a wide variety of controlled situations and to determine how the process changed across them. The basic question asked of reading comprehension processes was:

"When is what information used by whom in what situations (where)?"

The four "wh-" question words defined the four classes of variables that were factors that were manipulated in the course of the research project.

(a) What? What information is there in the input that is used by the processing components? Many comprehension models have assumed that there is a one-to-one match between information types and processing components. For example, there is a phonological component that processes phonological information, a syntactic component for syntactic information, a semantic component for semantic information, and so on. However, each processing component, say lexical access, may use several kinds of information, e.g., phonological or graphic, syntactic, and semantic, to recognize a word. Likewise, a given type of information may be used by several processing components, for example, syntactic information may be used by lexical access, sentence comprehension, and discourse understanding. So the mapping between information types and processing components may be many-to-many rather than one-to-one.

(b) When? When during the process are the various information types used? An answer to this question necessitates an on-line measure of processing, one that is sensitive to the temporal structure of information use as well as to the different information types. If one is concerned about processing more than about representations, then the processes must be tapped while they are in action and not be reconstructed from changes in the representations. By mapping the time course of information use during processing, the temporal structure among the processing components can be identified.

(c) Who? Readers differ in the abilities, skills, past experience, and prior knowledge that they contribute to their own reading process. Children who are just learning to read probably process the printed information somewhat differently than do skilled adult readers. Prior knowledge, e.g., familiarity with the topic of the text, and text difficulty also affect the process. Languages differ in how they encode information in print, contrast logographic and alphabetic orthographies. How linguistic information is encoded may make some reading processes or strategies more efficient than others. So the language structure may alter the specific reading process.

(d) Where? The reading situation may alter the way the readers process the text. Why are they reading? What do they hope to get out of the text? What are they expected to do with the information? What are the output conditions for reading? The purpose for reading probably changes the kind of processing: whether readers are reading for pleasure, for specific information, for memorization, etc. The task demands are especially critical in experimental situations as well as in classrooms. If readers think that they are being evaluated according to some performance criterion, then they may alter their processing in an attempt to meet that criterion. Differences between listening and reading processes (Danks, 1980; Danks & End, 1981) and between silent and oral reading processes (Danks & Fears, 1979) may be due in large measure to the different demands imposed on the comprehender as processing is altered to meet the specific demands associated with each modality.

The remainder of this report is organized in terms of these four factors. None of the classes of factors operates independently in any specific reading situation, but they interact to produce a specific process, i.e., a specific organization of the components. How these factors interact to produce the specific processing structure is the focus. Although the factors are considered in separate sections, their interaction should color the interpretation of results. In the first section, manipulations of information types (What?) are described in terms of their effect on oral reading performance, an on-line measure of processing (When?). Then studies that evaluate readers that bring different skills to the reading situations (Who?) are described. In the next section, how reading processes vary in different situations with different task demands is investigated. Finally, theoretical implications about the nature of the reading process and implications for educational practice are drawn in a concluding section.

II. Input Information and Temporal Organization

Since most of the studies reported here used a similar rationale, design, procedure, and analysis, a modal experiment is described initially. Then as the various experiments are discussed, variations from that mode are mentioned as appropriate.

Modal Experiment

Rationale. Although oral reading is used frequently in schools to evaluate reading (Durkin, 1978-1979), its processing requirements are not fully understood (Danks & Fears, 1979). In contrast to silent reading, the dominant task demand in oral reading is that each word be uttered in serial order. To accomplish this task, each word is located in the mental lexicon and the articulatory information found there is used to pronounce it. A reader potentially could use lower-level information, such as grapheme-phoneme correspondences, spelling patterns, or syllabic structure, to pronounce a word without accessing it. However, since readers do not read pronounceable nonwords unhesitantly, dependence on lower-level information is unlikely. When oral reading is followed by a comprehension test, the reader also needs to understand the phrases, sentences, paragraphs, and main ideas of the text. Information from several levels must be integrated to construct a reasonable interpretation. During oral reading, the reader is attempting to satisfy both the verbal performance demand and the comprehension demand at the same time. Analysis of oral reading performance provides an excellent opportunity to study lexical access, sentence comprehension, and discourse understanding in a relatively natural situation.

In the experiments reported here, we investigated what kinds of information were used by the lexical access and sentence comprehension components. The oral reading task also permitted an estimation as to when the different types of information were being used. Specifically, the point in time when different types of information were processed was assessed by violating each information type. If that information were normally used in oral production or in comprehension, then oral performance would be disrupted because the normal interplay among processing components would be modified to compensate for the violation. Furthermore, the disruption would be temporally close to when the violated information was needed by the reader. The basic method was to change several critical words in a story, such that one or more types of information was violated. We then analyzed readers' oral productions for disruptions near each critical word. The relative position of the disruptions resulting from the different violations indicated the order in which the information was typically used.

In general, interpretation of results depends on the relative positions of disruptions across violations, not on the absolute location of a disruption. So if violation of one information type produced a disruption before another violation type, utilization of the two information types is temporally ordered as well, regardless of the absolute positions of the disruptions. In some cases, however, the absolute position is interpretable; for example, disruptions that begin after a critical word has been uttered cannot reasonably involve lexical access. The absolute

location of a disruption may reflect in part the eye-voice span, that is, the distance between where the eye is focused and the word being uttered (Levin, 1979). But the relative positions of disruptions is not compromised because the size of the eye-voice span can be assumed to be relatively constant for all manipulations on average since all violations occurred equally often in each critical word segment. The size of the eye-voice span may vary systematically in other comparisons, such as in the results from different readers, e.g., children at different levels of reading skill, or results from different texts, e.g., easy or difficult stories. In these cases, the effect of possible changes in the size of the eye-voice span must be considered.

Interpretive models predict that disruptions resulting from having violated different types of information would be ordered from earliest to latest according to the level of abstraction of the violated information. The least abstract information would produce the earliest disruption, followed by disruptions from violating more abstract information types. For example, a spelling violation would produce a disruption before a syntactic violation and both would be before a disruption from a factual violation. Interactive models posit that several types of information are used in the same component and so the violations would produce similar disruption patterns. Such models also permit more than one component to operate at the same time, so that different information types might be used at the same time by different components. Both types of interaction predict that violations of different information types result in disruptions that occur at the same time.

Materials and violations. A 2171-word story (readability = 7.8, Fry, 1968) was adapted from a popular American magazine. It was about a high school girl who was severely injured when a train hit her school bus. Critical words were selected at widely scattered points in the story. A sample portion of the story surrounding the critical word, injured, is shown in Figure 1. The girl's mother has just heard about the accident and is worried about her daughter. One or two types of information were violated across several experiments: physical, spelling, lexical, between- and within-syntactic, semantic, and factual. Each information type could be violated either by itself (a single violation) or in combination with another information type (a double violation). Each of the single and double violations for the example in Figure 1 are listed in Figures 2 and 3, respectively.

(a) Physical. Physical information was violated by covering portions of the letters of the critical word with opaque correction fluid. The portions covered were determined somewhat arbitrarily, but each letter was covered to some extent. Enough of each letter remained so that the word was still identifiable. With extra attention, readers could identify the critical word and locate it it their mental lexicons, but the initial processing would be disrupted.

(b) Spelling. To violate orthographic information, the critical word was misspelled, e.g., injured was misspelled injerd. If the readers "sounded out" the misspelled word, however, they would arrive at a pronunciation that was the same or very near to that of the critical word. Thus, lexical access would be disrupted, but the readers could locate

Her daughter had always been [weak] physically. Because of this, she even

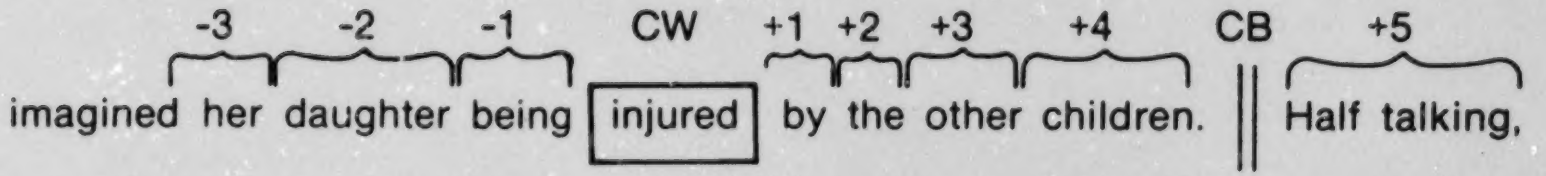

Figure 1. A sample portion of text around the critical word, injured.

EXAMPLES OF SINGLE VIOLATIONS

Violation Condition	*Critical Word*	*Preceding Sentence*
Control	**injured**	**weak**
Physical	**injured**	**weak**
Spelling	**injerd**	**weak**
Lexical	**separned**	**weak**
Between-Syntactic	**injury**	**weak**
Within-Syntactic	**injures**	**weak**
Semantic	**planted**	**weak**
Factual	**injured**	**strong**

Figure 2. Example violations of single information types for the critical word, injured.

EXAMPLES OF DOUBLE VIOLATIONS

Violation Condition	*Critical Word*	*Preceding Sentence*
Physical + Spelling	**inierd**	**weak**
Physical + Lexical	**sopurned**	**weak**
Spelling + Semantic	**plantid**	**weak**
Spelling + Factual	**injerd**	**strong**
Between-Syn + Factual	**injury**	**strong**
Within-Syn + Factual	**injures**	**strong**

Figure 3. Example violations of double information types for the critical word, injured.

the word in the mental lexicons through phonological information. From that point, processing could proceed without disruption.

(c) Lexical. The critical word was replaced with a pronounceable nonword, e.g., separned replaced injured, in order to violate lexical information. The nonword followed the rules of English orthographic structure and was readily pronounceable. Insofar as possible, certain characteristics of the critical word, such as initial and final letters, word shape, morphological endings, etc., were retained in the nonword. Since the nonword could not be found in the readers' mental lexicons, lexical access would be disrupted and word recognition would be impossible.

(d) Between-Syntactic. Syntactic information was violated in two ways. One way was to change the critical word to a different part of speech, i.e., between syntactic categories. The root morpheme was retained, but the inflection was changed such that it indicated a part of speech that could not occur at that point in the sentence. In the example, injured, a verb, was changed to injury, a noun. Although some semantic information is carried in the syntactic categories, most of the semantic information remains in the root. The influence of syntactic category information on lexical access and sentence comprehension could be assessed.

(e) Within-Syntactic. The second way of violating syntactic information made the change within part-of-speech categories. The inflection was changed within the same part of speech, but in a way that produced a syntactic violation. In the example, injured was changed to injures, both of which are verbs. This violation, in comparison with the between-syntactic, provided evidence on how sensitive readers were to different types of syntactic information.

(f) Semantic. To violate semantic information but not disturb lexical or syntactic information, the critical word was replaced with a word that was the correct part of speech but that was semantically anomalous. In the example, planted replaced injured. Although readers could determine syntactic structure, they had to concoct an implausible meaning. The best they could do was to imagine unusual circumstances in which the anomalous word could be interpreted metaphorically.

(g) Factual. Factual information is what the reader accumulates from the proceeding text while reading a story. Factual information was violated by introducing an inconsistency between the critical word and the preceding sentence. Unlike the other manipulations, neither the critical word nor the sentence containing it was altered. The sentence immediately before the sentence with the critical word was altered such that the critical word was factually inconsistent with the sense of the altered sentence. In the example, the word weak in the preceding sentence was replaced with strong. The fact that her daughter was strong was inconsistent with the mother worrying about her being injured. There was nothing syntactically or semantically wrong with either sentence. They simply communicated inconsistent information.

(h) Control. In a control condition, there was no change in the critical word, nor in the preceding sentence. This condition served as

a baseline for "normal" reading and provided an estimate of unprovoked oral reading errors.

Six double violations were used in some of the experiments (see Figure 3). They were formed by combining two of the single violations in one critical word. Not all combinations were possible in practice. The following were used.

(a) Physical + Spelling. Parts of the letters of the misspelled critical word were covered with opaque correction fluid.

(b) Physical + Lexical. Parts of the letters of the pronounceable nonword were covered.

(c) Spelling + Semantic. The semantically anomalous word was misspelled, e.g., plantid.

(d) Spelling + Factual. The critical word was misspelled and the preceding sentence was altered to produce an inconsistency.

(e) Between-Syntactic + Factual. The part of speech of the critical word was changed as well as the factual information in the preceding sentence.

(f) Within-Syntactic + Factual. The critical word was changed within the same part of speech and the preceding sentence was altered.

All modifications were selected to assure that the readers would be unlikely to conceive of a continuation after the critical word that would eliminate the violation. In any given experiment, each violation occurred an equal number of times in the story. There were different versions of the story equal to the number of different kinds of violations, such that each violation type occurred once at each critical word across versions. The stories were typed so that critical words did not occur near the beginnings or end of lines, nor near the tops or bottoms of pages.

Procedure. All subjects were native English speakers and were not screened for reading ability. None participated in any other oral reading experiment. Ten subjects read each version of the story. Subjects were tested individually. They were told that the purpose of the experiment was to examine the relationship between reading and comprehension. They were instructed to read each section aloud, and then to write a summary of it. They were given as much time as they needed to read and to summarize the story. The reading performances were tape recorded for later analysis. In order to provide some warm-up for the readers, the first critical word did not occur until the lower portion of the first page.

Analyses. In fluent speech, each word is not spoken with clearly distinguished beginning and ending sounds as it would be spoken in isolation. Two words may be uttered as if they were one long word with no break separating them. Other words are pronounced with a break in the middle. Because of these possibilities, the text surrounding each critical word was divided into word units in order to facilitate measurement of

disruptions. Word units were specified by listening to several readers and dividing the text surrounding the critical words into groups that were pronounced as a unit. The most consistent phraseology across readers was adopted. In the early experiments, word units typically consisted of one or two words, rarely three words, and did not necessarily follow the syntactic structure of the sentence. In the later experiments, each word was usually a separate word unit. The number of word units before and after each critical word varied across experiments.

Two dependent variables were measured: production times and major disruptions. The production time for each word unit was measured by slowing the tape recorder to half-speed. An experimenter then pressed a key at the end of each word unit. A lab computer monitored the key presses and timed the latencies between them. Each interval included the production time for the word unit itself as well as any pause, hesitation, or filler words that preceded the word unit. It was impossible to have an experimenter who was blind to the experimental manipulations measure the production times because any English speaker would recognize the violations on hearing the taped protocols. In order to assess the extent of experimenter error in measuring the production times, inter- and intra-experimenter reliabilities were obtained. The average correlation between two experimenters was .94 and between two timings by the same experimenter was .98. Finally, production times measured from sound spectrograms correlated .91 with an experimenter's timing. Thus, the procedure for measuring production times was reliable.

The second dependent variable was the probability of a major disruption at each word-unit position. Major disruptions were defined as pauses, substitutions, omissions, reversals, stammerings, mispronunciations, repetitions, and regressions. In short, any deviation from fluent oral reading that indicated that the reader noticed a violation was scored as a major disruption. Only one disruption was tallied per word unit and the frequencies were converted to probabilities. The major disruption data matched the results of the production times as well as providing qualitative information about the disruptions. Since the correlation between production time means and major disruption means was .93, only major disruptions were scored in the later experiments. Only major disruption results are reported here for the same reason. Production time results for some experiments are reported in the papers in the appendices.

Both dependent variables were analyzed with a mixed analysis of variance. Groups of readers, as defined by the story versions, was a between-subjects factor. Type of violation, word-unit position around the critical word, and specific critical word segment were within-subject factors. Versions, violation types, and segments were arranged in a Latin-square. This design permitted calculation of a quasi-F ratio (F') in which both subjects (individual readers) and language materials (critical word segments) were random factors contributing to a single error term (Clark, 1973). The interaction of violation type with word-unit position was the critical test. The means for violation types were compared to the control means at each word-unit position using individual planned comparisons (Winer, 1971), based on the quasi-F mean-square error term. All reported effects were significant with $p < .05$.

Studies of Information Violations

Experiment 1. The first experiment violated syntactic + semantic, semantic, and factual information. The mean differences in the probability of a major disruption between the violations and the control condition are shown in Figure 4.

Both the syntactic + semantic and the semantic violations produced a disruption at the word unit before the critical word (word unit -1). The peak disruption from the syntactic + semantic violation was significantly larger than that resulting from the semantic violation alone, but the semantic violation had a longer lasting effect, remaining significantly different from the control at word units +3 and +5. Since both syntactic + semantic and semantic violations yielded disruptions before the critical word was produced, both syntactic and semantic information were being used during lexical access. Both violations were also disruptive after the critical word was produced, indicating failures during sentence comprehension as well. The factual inconsistency was disruptive only after the critical word had been uttered (word unit +1). So factual information was not involved in lexical access, but only in sentence comprehension.

The syntactic + semantic violation had a larger disruptive effect earlier than did the semantic violation. A violation in both of two independent information sources would be noticed before a condition in which only one source was violated. So the syntactic + semantic violation may have been a violation of two independent knowledge sources. The next experiment separated the syntactic and semantic violations and attempted to enhance the factual violations.

Experiment 2. The second experiment used the same story as the first, but several of the factual violations were rewritten to make them even more inconsistent, and the syntactic + semantic violations were replaced with (between-) syntactic violations.

As shown in Figure 5, the syntactic and semantic violations produced very similar disruption curves. Both were significantly different from the control at word unit -1 and peaked at the critical word. The semantic violation produced a slightly longer disruptive effect (to word unit +3) than did the syntactic (only to word unit +2). The biggest difference was in the magnitude of the disruption at the critical word. Most of the disruptions in the syntactic violation (54% of all disruptions) were restorations of the correct part of speech. Excluding restorations of the original critical word from the syntactic and semantic conditions, the proportions of disruptions at the critical word were virtually identical--.33 for syntactic and .34 for semantic. The restoration of the original critical word in the syntactic violation condition was a top-down effect resulting from syntactic constraints on the part of speech. Syntactic + semantic violations were never restored in the previous experiment. So the difference between syntactic + semantic and semantic-only disruptions observed in the first experiment evidently resulted from the combined effect of violations of two independent knowledge sources.

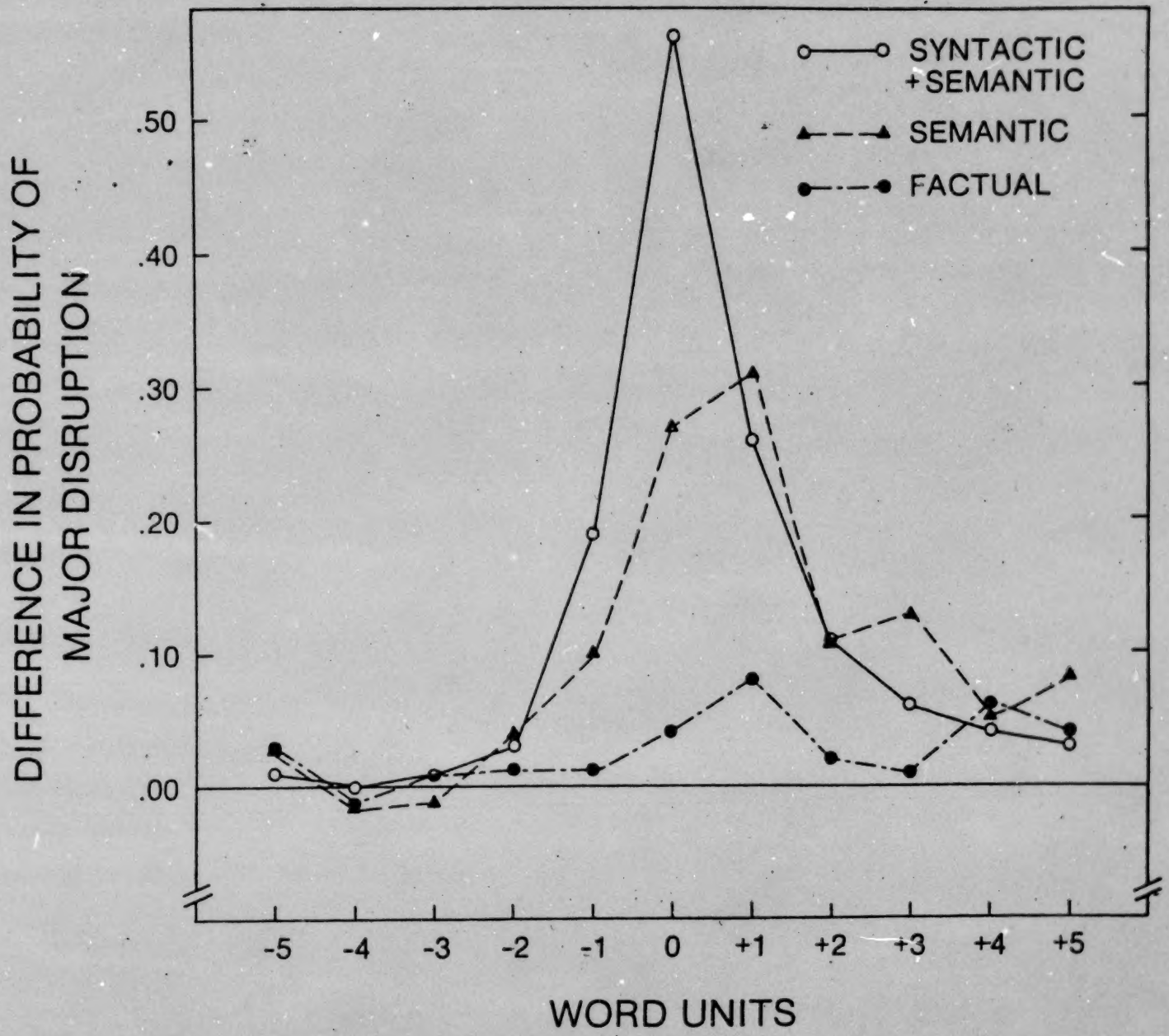

Figure 4. Experiment 1: Disruption curves for syntactic + semantic, semantic, and factual violations.

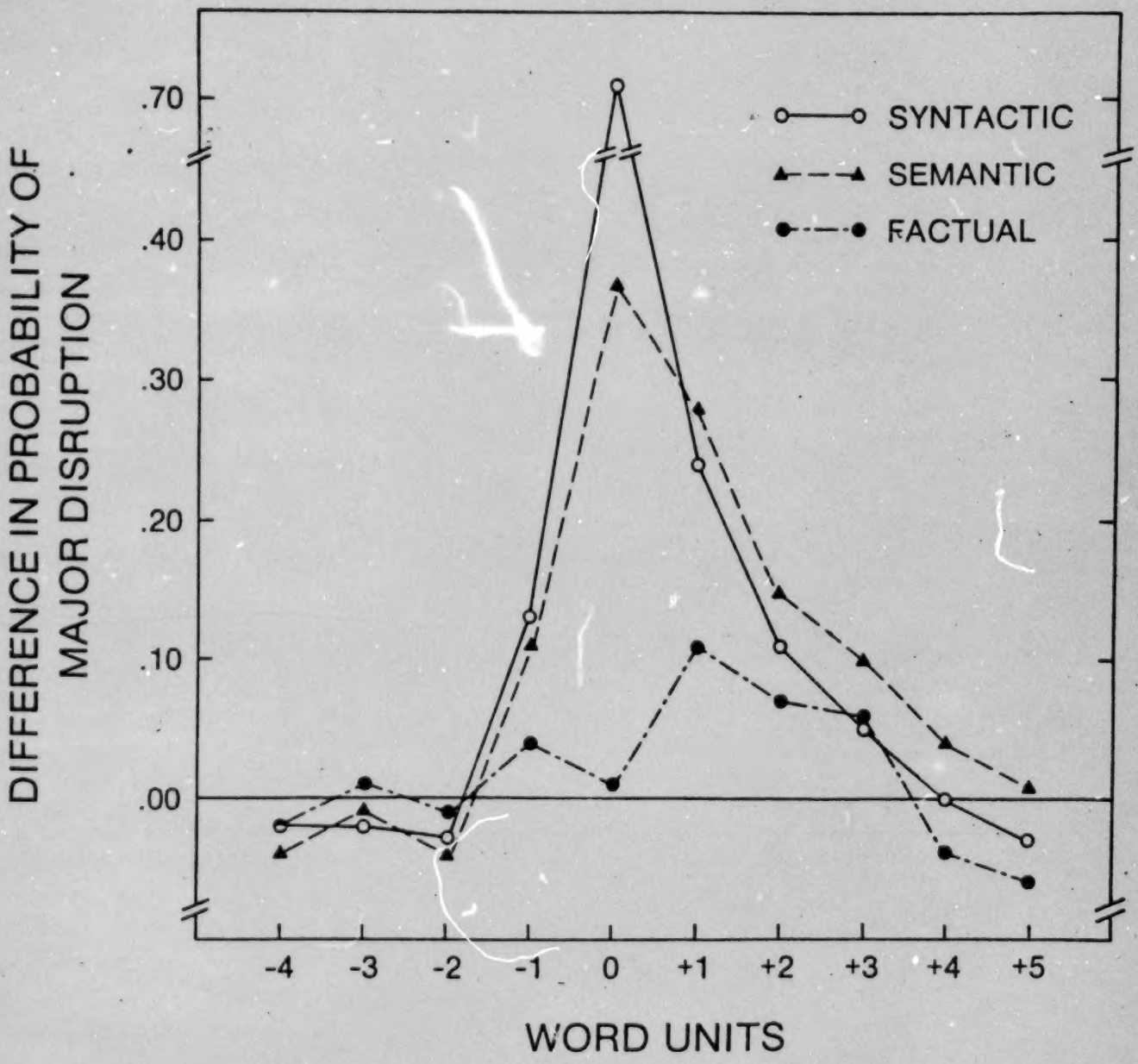

Figure 5. Experiment 2: Disruption curves for syntactic, semantic, and factual violations.

The factual violation produced a larger effect than in the preceding experiment, but it still was first effective at word unit +1 and not at or before the critical word. In contrast to syntactic and semantic information, factual consistency did not have any apparent influence on lexical access of the critical word, but was involved in sentence comprehension.

Experiment 3. The third experiment used 12 paragraphs averaging about 125 words each from a contemporary novel. One critical word was selected in each paragraph. Lexical, syntactic + semantic, and semantic violations and controls were introduced at three critical words each.

As shown in Figure 6, the principal point of disruption resulting from lexical violations occurred at the critical word. Most of these disruptions were pauses as the readers hesitated before uttering the pronounceable nonword. Unable to locate that lexical item in their mental lexicons, they balked and sometimes had difficulty in pronouncing the nonwords just on the basis of phoneme-grapheme correspondences. The disruptions from the syntactic + semantic violation followed the disruption from the lexical almost perfectly. They both differed significantly from the control at the critical word and at word unit +1. Syntactic or semantic information or both were being used to locate the lexical item, so that removal of that information disrupted the readers. Since the patterns of disruption resulting from the lexical and syntactic + semantic violations were essentially the same, these information sources must have been active at the same time, although they may have operated independently.

The disruption from the semantic violation did not occur until word unit +1, however, and was relatively smaller. In reading this story, semantic information was not being used for lexical access. The violation was discovered later, perhaps when sentence integration occurred. This result may have occurred because the story was excerpted from a novel that was written in an abstract, metaphorical style. The semantic violations were anomalies that easily could have been mistaken for intentional but incomprehensible metaphors. The readers adopted the quite reasonable strategy of not giving high priority to semantic information because it was frequently figurative or anomalous.

Violations of lexical, syntactic, and semantic information disrupted oral production at about the same point before the critical word was uttered. From the perspective of lexical access, lexical information is bottom-up, and syntactic and semantic information are top-down. Yet the pattern of their disruptive effects was quite similar. All three information sources were contributing to lexical access. When any one information source was violated, the normally automatic process of lexical access was disturbed, forcing a reliance on careful bottom-up processing to be sure what word was actually printed.

The occurrence of disruptions for several word units after the critical word represented more than a simple perseveration of the initial disruption, however. After the critical word had been uttered, the reader attempted to make sense of the inserted word. How could the clause be interpreted so that the word would not be inconsistent with the representation the reader was constructing for the sentence, paragraph, and story? This comprehension difficulty was evident with all violations,

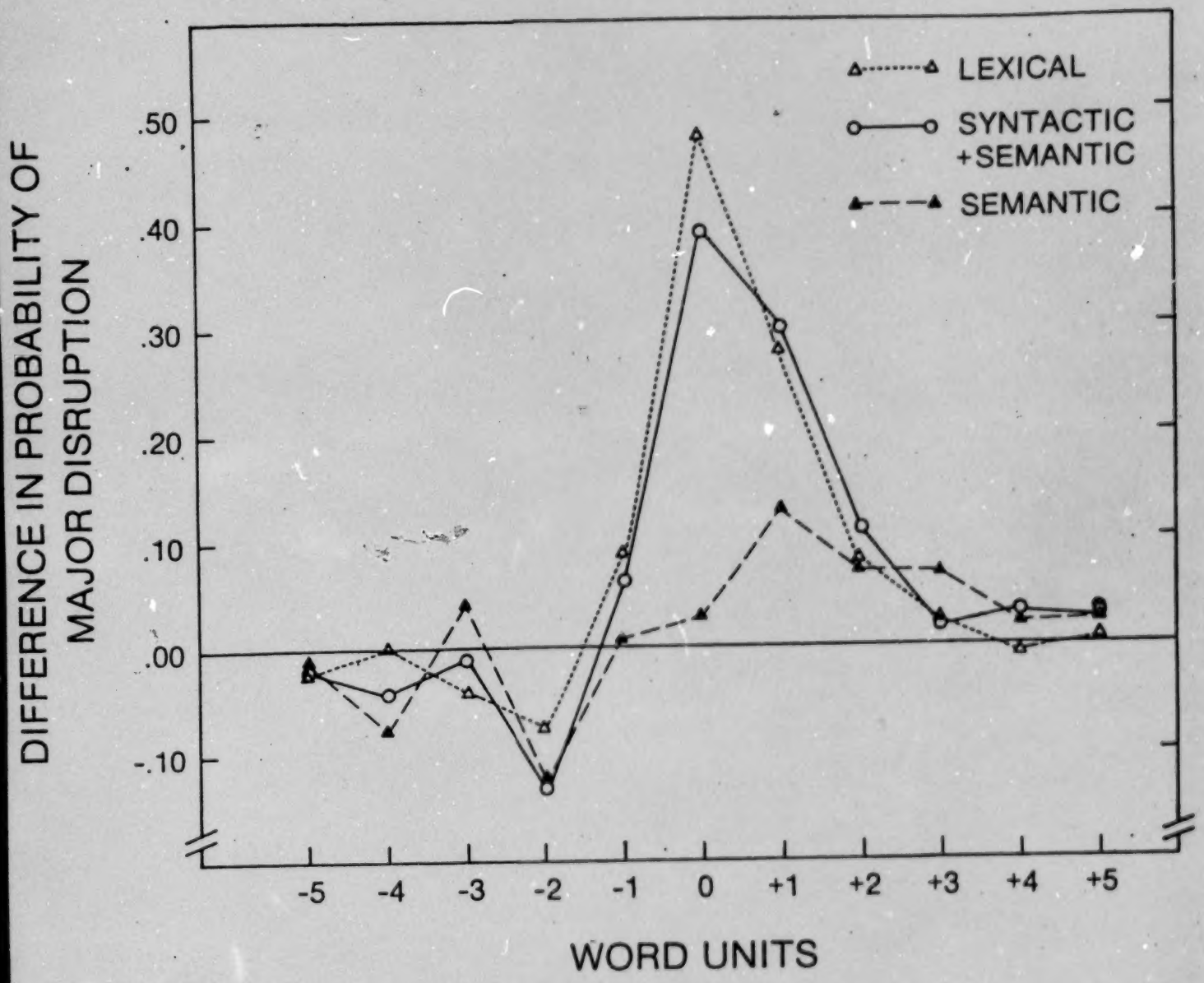

Figure 6. Experiment 3: Disruption curves for lexical, syntactic + semantic, and semantic violations.

including the factual. Even though the disruption from the factual violation was much smaller, it occurred consistently for several words after the critical word.

Were the post-critical word disruptions synchronized with the end of the clause? In preparing the stories, we did not attempt to control the location of the clause boundaries after the critical words. However, a post hoc analysis of the data in the first two experiments suggested that there may have been a peak of disruption at the clause boundary. If so, then such disruptions would provide strong evidence for the operation of a sentence comprehension component. However, the data from the first three experiments were too few to draw strong conclusions about whether there were disruptions at the clause boundary.

Experiment 4. Three experiments (4A, 4B, and 4C) then were conducted to investigate the question of processing at the clause boundaries. All three experiments tested 40 college student readers each, using factual and control conditions. Experiments 4A and 4B used only the factual and control manipulations. Experiment 4C used factual and case alternation crossed with control. In the case alternation violation, the critical word was printed with letters in alternating cases, e.g., InJuReD. Case alternation produced a significant disruption only at the critical word and did not interact either with the factual violation nor with the location of the clause boundary, so its effects are not considered further. The location of the clause boundary following the critical word coincided with the end of the critical sentence. For four of the critical words, the clause boundary was located immediately after the critical words (zero word units = CB 0). For four more critical words, it was two words after the critical word (two word units = CB +2). For four more critical words, it was four words after (three word units = CB +3). And for the last four critical words, it was eight words after (six word units = CB +6). The location of the clause boundary was completely crossed with factual and control manipulations and with quarters of the story.

The disruption curves for the four clause boundary locations are shown in Figure 7, collapsing across all three experiments. Although the data were somewhat variable, significant peaks of disruption occurred at the word unit after each clause boundary, i.e., CB 0 had a disruption at word unit +1, CB +2 had one at word unit +3, CB +3 at word unit +4, and CB +6 at word unit +7. There were some other unexplained peaks, such as at word unit -1 for CB +2 and at word unit +8 for CB +3. Thus, there was a clause boundary effect, at least for the use of factual information, indicating that the sentence comprehension component was operating at that point. Which of the other information types also are used by sentence comprehension was investigated in the next experiment.

Experiment 5. In this experiment the number of critical words was increased from 16 to 24 by adding two new critical words to each quarter of the story. Each clause boundary location was represented by six critical words. Three single and two double violations were introduced in addition to the control--spelling, semantic, factual, spelling + semantic, and spelling + factual. Each of the violations occurred once at each clause boundary location. There were six versions of the story in which violations and clause boundary locations were counterbalanced across specific critical words.

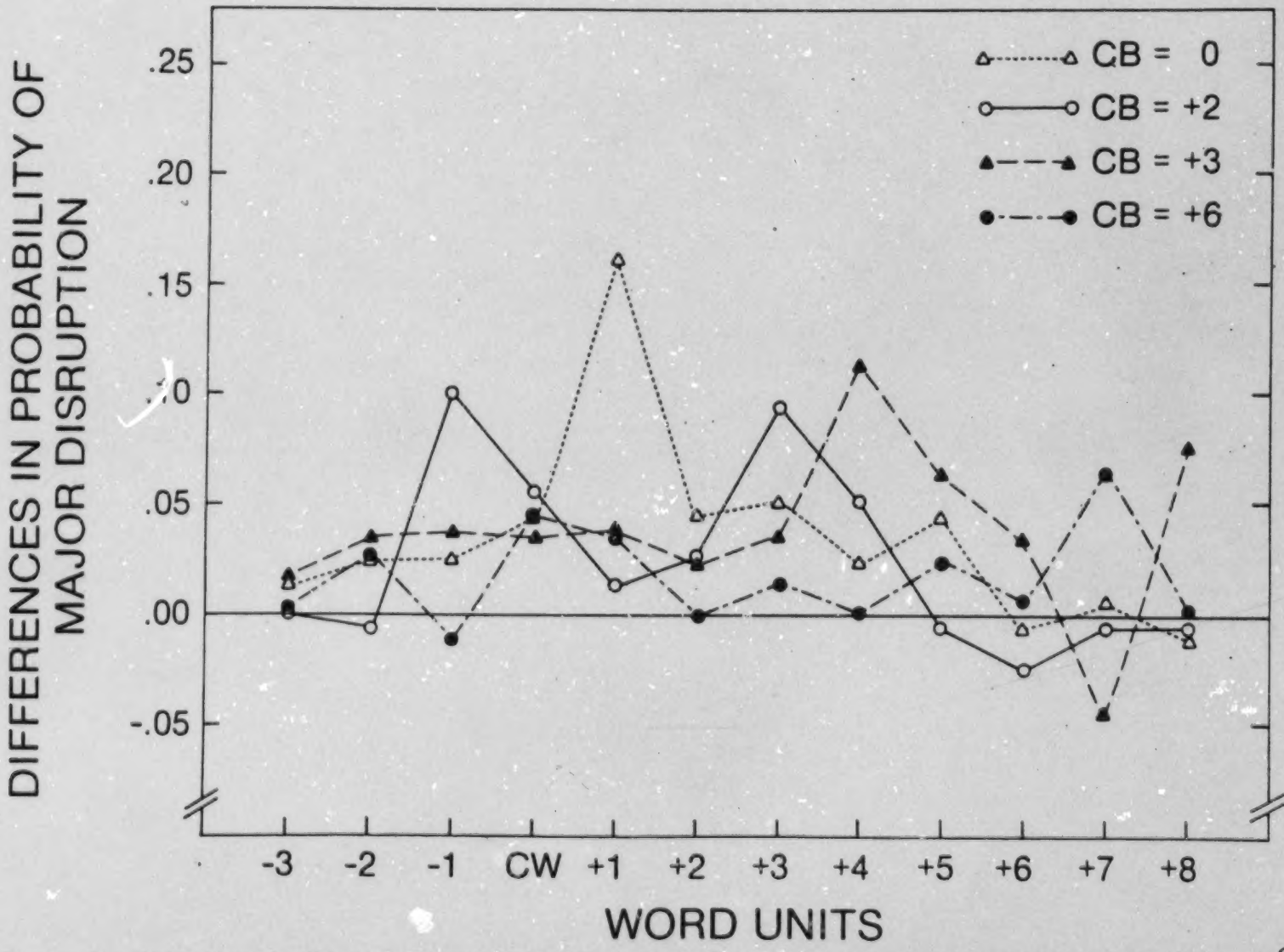

Figure 7. Experiment 4: Disruption curves for factual violations at four clause-boundary locations.

The disruption curves for the five violations are shown in Figures 8, 9, 10, and 11 for CB 0, CB +2, CB +3, and CB +6, respectively. All violations produced significant disruptions at or immediately after the critical word was uttered. Those from the spelling and semantic violations were larger than from the factual, but all were significantly different from the control. There also were some significant disruptions immediately following the clause boundaries, especially for the semantic and factual violations. However, these disruptions were not always evident at all clause boundary locations, primarily because of large variances. In this experiment each reader encountered only one critical word in each of the 24 conditions, i.e., six violations at four clause-boundary locations. Hence, there was too much variability in the data to yield clear results. In the next series of experiments, the location of the clause boundary following the critical word was controlled at exactly four words (and four word units) for all 24 critical words, so each reader encountered four critical words at each of six violation types.

Studies of Processing Components

The initial experiments on information violations supported the notion of separating information sources from processing components. In particular, lexical access, as reflected in disruptions immediately before and at the critical word, used lexical, syntactic, and semantic information. Sentence comprehension, as reflected in disruptions after the critical word was uttered, used semantic, syntactic, and factual information. However, the identification of the information sources used in sentence comprehension was not very clear, in large measure because the location of the following clause boundary was uncontrolled. Because the location of the clause boundary varied over a wide range, averaging tended to blur any disruptions that might have occurred at that point. While it is probable that sentence comprehension is a continuous process that operates even before a clause boundary is reached, its effects are more likely to be evident at the clause boundary. If the reader waits too long to finalize a representation and to integrate it with preceding propositions, short-term storage would overflow. The clause boundary provides a convenient point for such integrations.

The next three experiments, then, investigated a wider range of information violations, both single and double. The location of the clause boundary was controlled, which permitted a clearer separation of processing components, in particular sentence comprehension from lexical access. Also more information types and combinations permitted better specification of what types of information were used by these components and what information sources interacted in each.

Experiment 6. The story about the high school girl who was injured in a school bus accident was modified to include 24 critical words and to end the clause containing the critical word (as well as the critical sentence) exactly four words after the critical word. In addition to controls, there were five violation types inserted into the story--physical, spelling, lexical, spelling + physical, and lexical + physical. The presence of disruptions in the oral productions was scored for three words before and for eight words after each critical word. Otherwise, the procedure and scoring were the same as in the earlier experiments.

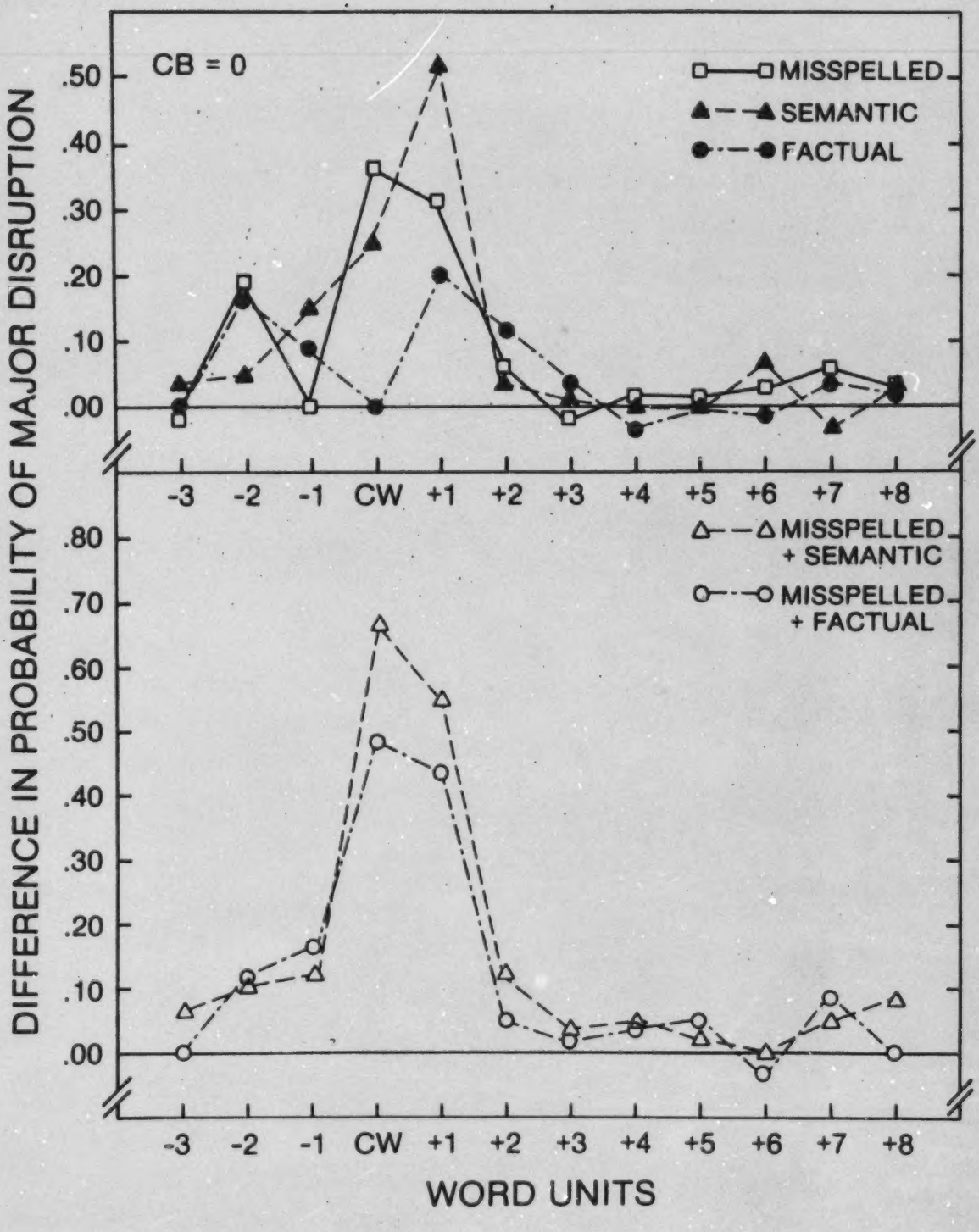

Figure 8. Experiment 5: Disruption curves at clause boundary of 0.

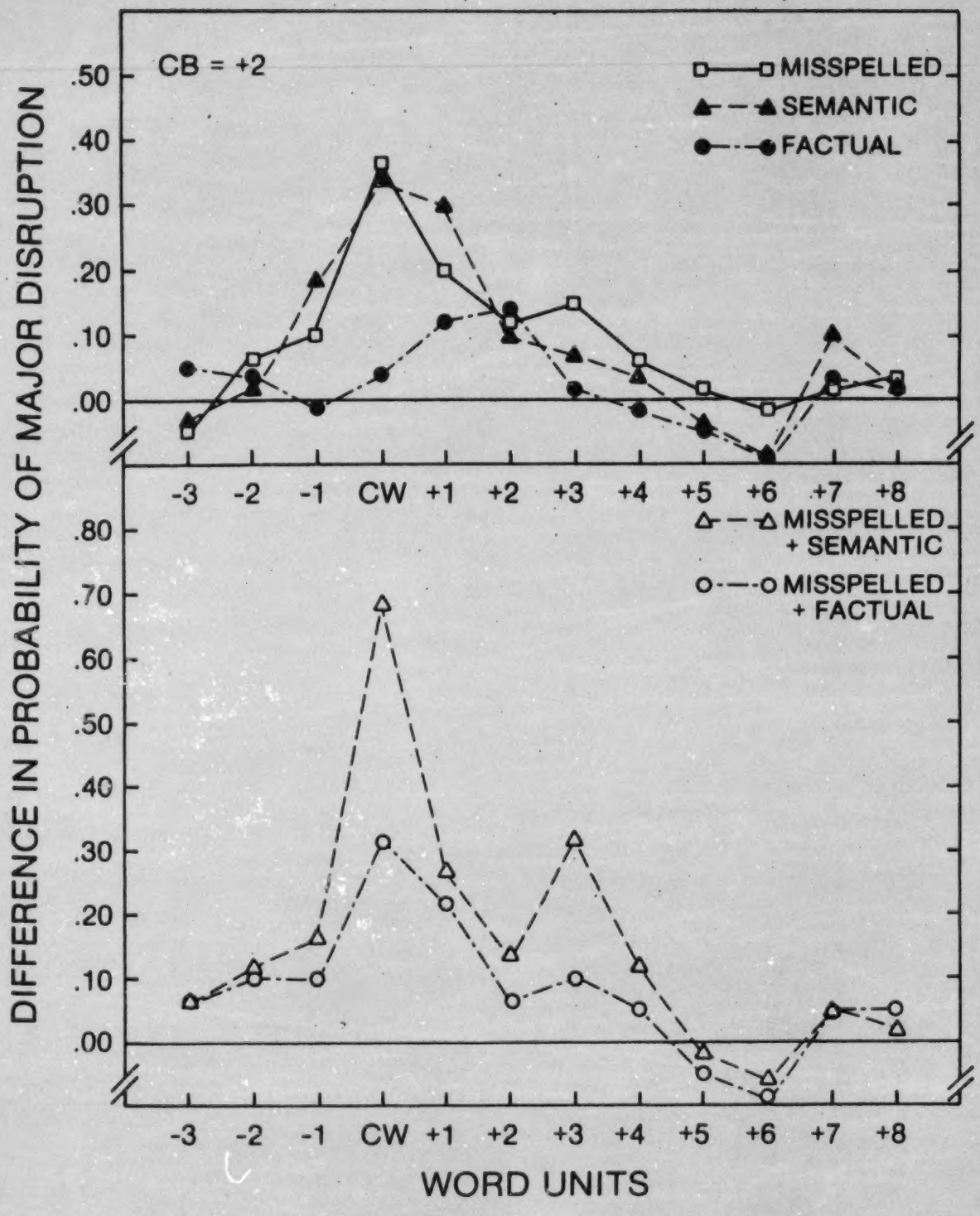

Figure 9. Experiment 5: Disruption curves at clause boundary of +2.

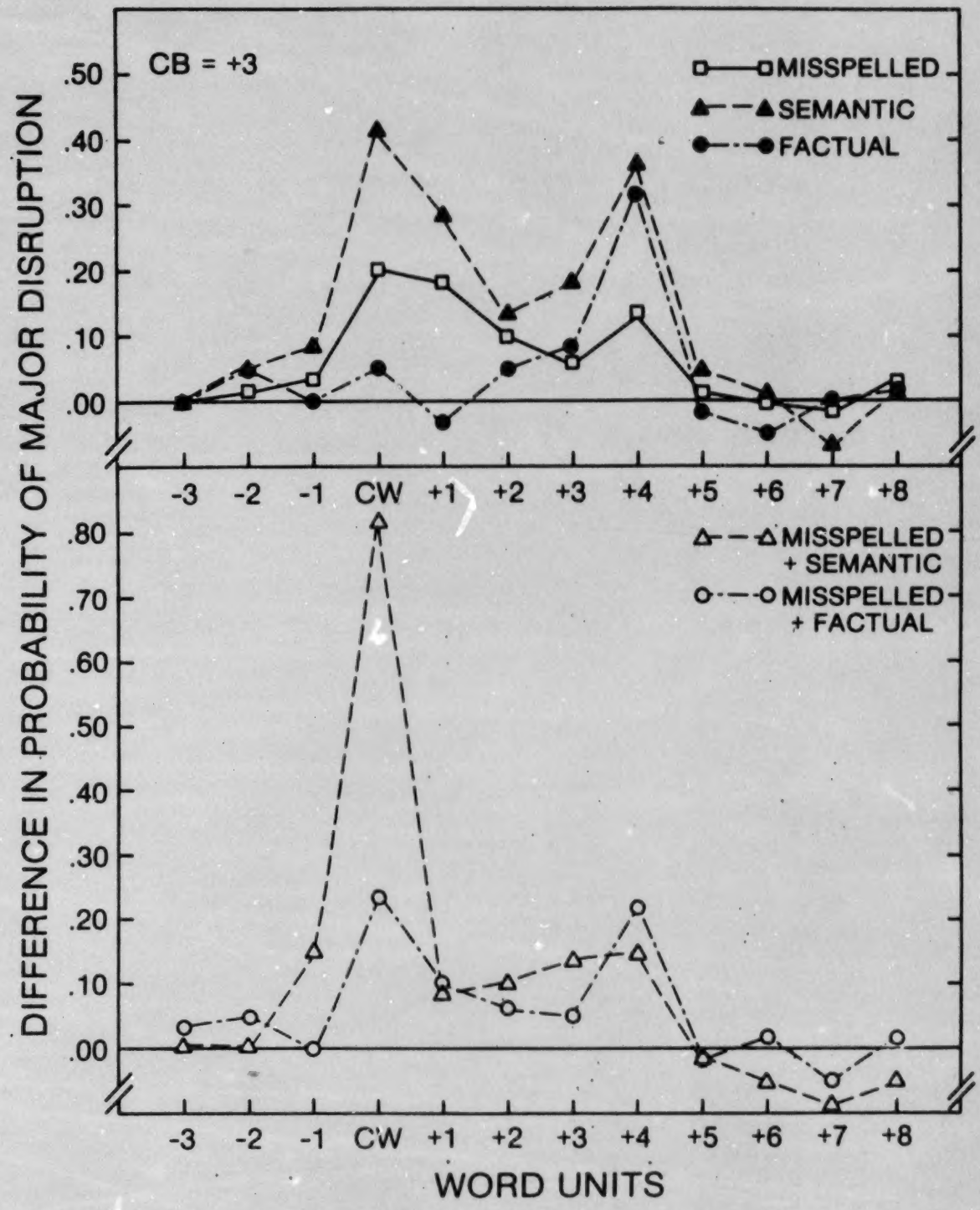

Figure 10. Experiment 5: Disruption curves at clause boundary of +3.

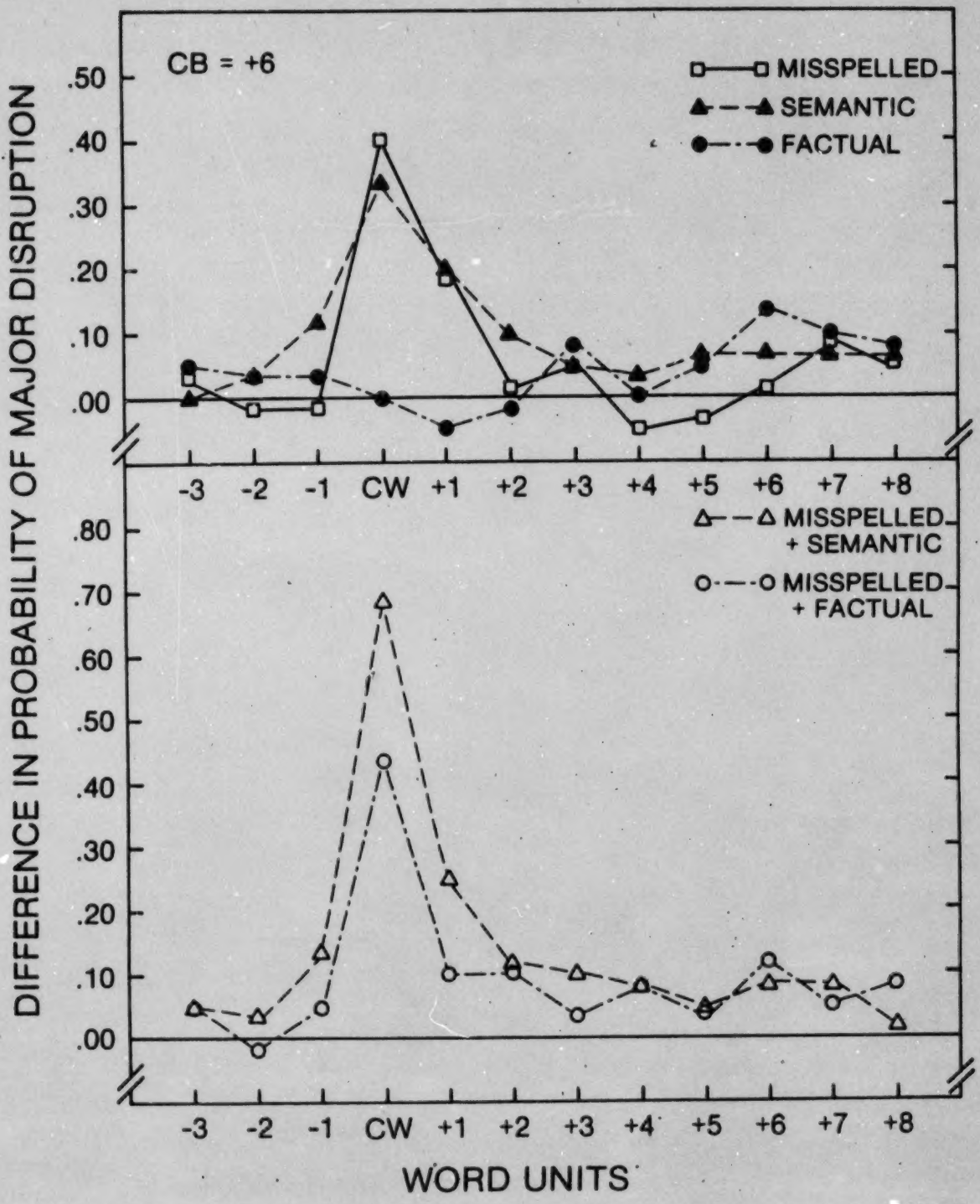

Figure 11. Experiment 5: Disruption curves at clause boundary of +6.

In order to simplify the computation of a quasi-$\underline{F}$ ratio, the Latin-square design was replaced with a factorial analysis of variance. Subjects reading each version were rank ordered in terms of the total number of oral reading disruptions they produced in the control condition only. Then the subjects with the lowest number of control disruptions for each version were matched, the subjects with the second lowest number of control disruptions, those with the third lowest number of control disruptions, and so on were matched until all ten subjects who read each version were matched with five other subjects reading each of the other five versions. These matched subjects were treated as single subjects in an analysis of variance with violation type (6 levels), word-unit position (12), critical words (24), and matched subjects (10) as factors. With this design, the violation-type-by-word-unit-position interaction was tested against both critical-word and matched-subject error variances simultaneously as recommended by Clark (1973). The matching procedure, if anything, was a conservative test, since variance due to version differences and individual differences among matched subjects contributed to subject-error variance rather than to version and between-subject variances in the Latin-square design.

The disruption curves are shown in Figure 12. Both single and double violations involving physical information produced significant disruptions beginning two word units before the critical word was uttered (word unit -2). As shown in later experiments, only physical violations produced disruptions so early. This result suggests that there is a processing component operating before lexical access that uses at least, and perhaps primarily, visual information based on the physical characteristics of the print. From our introspections while reading the texts, readers could detect a physical violation in the periphery of earlier eye fixations, but could not detect any of the other violations so early. Once resolved, physical information was not involved in sentence comprehension since there was no disruption at the clause boundary (word unit +5).

Both spelling and lexical violations produced disruptions near the critical word, the lexical beginning at word unit -1 and spelling at the critical word. The lexical violation produced a larger disruption earlier than did the misspelling indicating that readers detected the lexical violation earlier and had greater difficulty resolving it. The lexical violation alone produced a disruption before and after the clause boundary (word units +3, +4, and +5), whereas the spelling violation did not. Once the spelling violation was resolved, i.e., the intended word was identified, it posed no further problem to sentence comprehension. But discovering a nonsense word, one that was not in the readers' mental lexicons, meant that a semantically important content word was missing from the sentence. The best that the reader could do was to infer a meaning for the unknown word from the context.

The double violations in general confirmed the results from the single violations except for the disruption at the clause boundary from the spelling + physical violation, neither of which produced a clause boundary disruption alone. A possible explanation, albeit speculative, is that after a double violation, readers paused at the end of the sentence to make sure that they had unscrambled the degraded, misspelled word correctly.

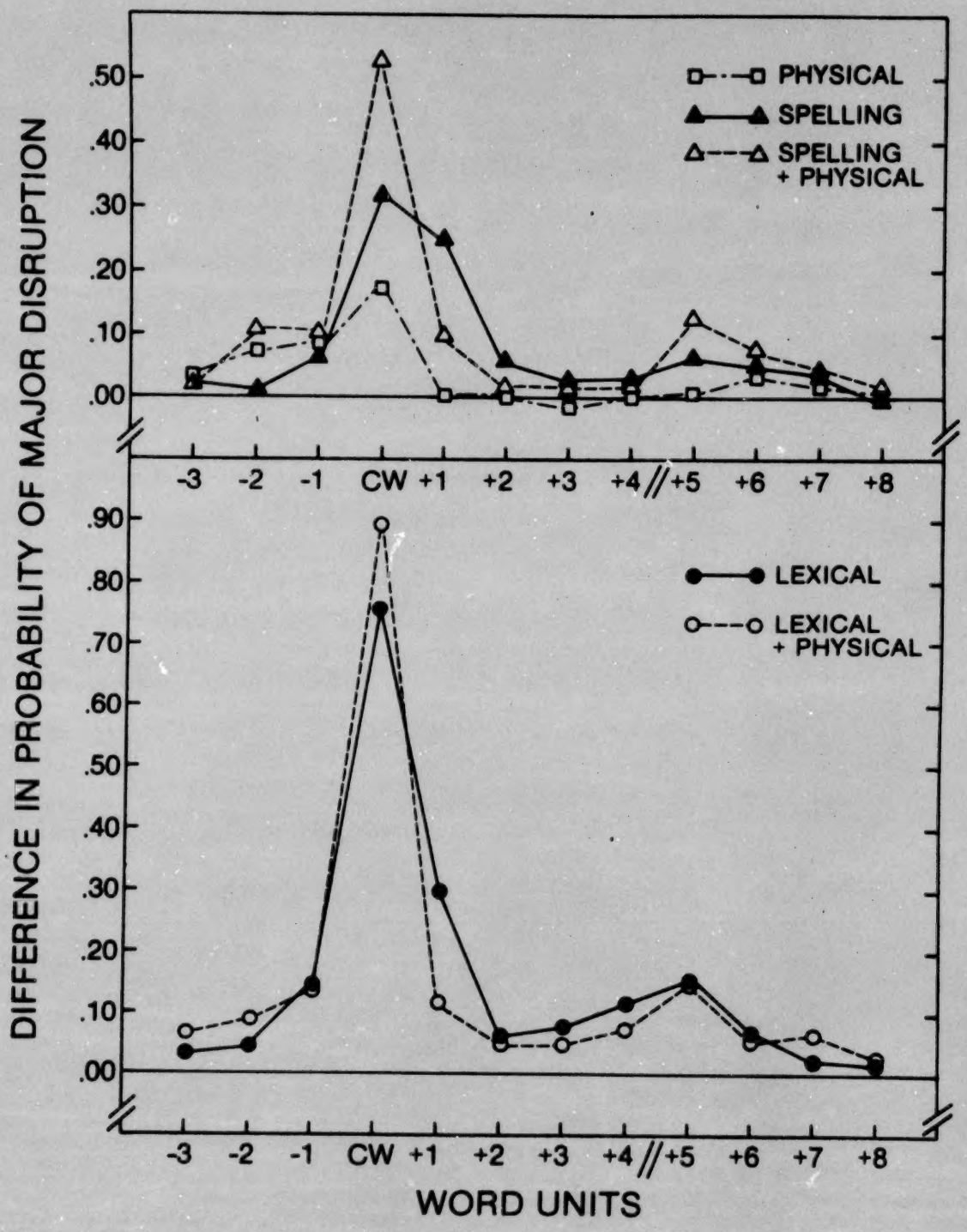

Figure 12. Experiment 5: Disruption curves for physical, spelling, and lexical violations.

Experiment 7. This experiment was exactly the same as Experiment 6 except that the five violations were between-syntactic, within-syntactic, factual, between-syntactic + factual, and within-syntactic + factual, plus control. The disruption curves are shown in Figure 13.

Both syntactic violations produced nearly identical disruptions both in general shape and in magnitude, alone and in combination with a factual violation. The syntactic violations disrupted lexical access beginning one word unit before the critical word and disrupted sentence comprehension at word unit +5. Syntactic information was used both in lexical access and in sentence comprehension, but English readers generally were insensitive to the level of syntactic category violated. There were small differences in the number of restorations of the original critical word. The between-syntactic violations yielded only 22% restorations of which 47% were fluent, whereas the within-syntactic violations produced 28% restorations of which 58% were fluent. So there was a slightly greater tendency to restore the less extreme within-syntactic violations and the more extreme between-syntactic ones, and to do so fluently. These results contrast with the between-within-syntactic results for Polish readers (reported in section III), in which a large difference resulted from the two violations.

The factual violation produced a significant disruption only at the clause boundary (word unit +5) and enhanced disruptions at the clause boundary in combination with the syntactic violations. These results confirmed the earlier results from Experiments 1 and 2 that factual information was not used in lexical access, but was involved in sentence comprehension. With the clause boundary separated more cleanly from the critical word, the sentence comprehension effects were more pronounced.

Experiment 8. The violations used in this experiment were spelling, semantic, factual, spelling + semantic, and spelling + factual, plus control. Otherwise, the materials, procedure, scoring, and analyses were identical to those used in the two preceding experiments. The disruption curves are shown in Figure 14.

The spelling violation produced a significant disruption only at the critical word and immediately after (word unit +1). The semantic violation produced a significant disruption that began one word before the critical word and continued through word unit +5. And the factual violation produced a disruption only at the clause boundary (word unit +5). These three results confirmed previous findings for these violations --the semantic from Experiment 2, the spelling from Experiment 6, and the factual from Experiment 7. Spelling and semantic information, but not factual, were used in lexical access, but only semantic and factual information, but not spelling, were used in sentence comprehension. Top-down semantic information even may be more important in lexical access than is bottom-up spelling information because the semantic disruption began one word unit before the spelling disruption. The semantic disruption was significantly larger at word unit -1, even before the critical word was uttered.

The double violations basically were additive combinations of the single disruptions, indicating that the three information sources were operating more or less independently.

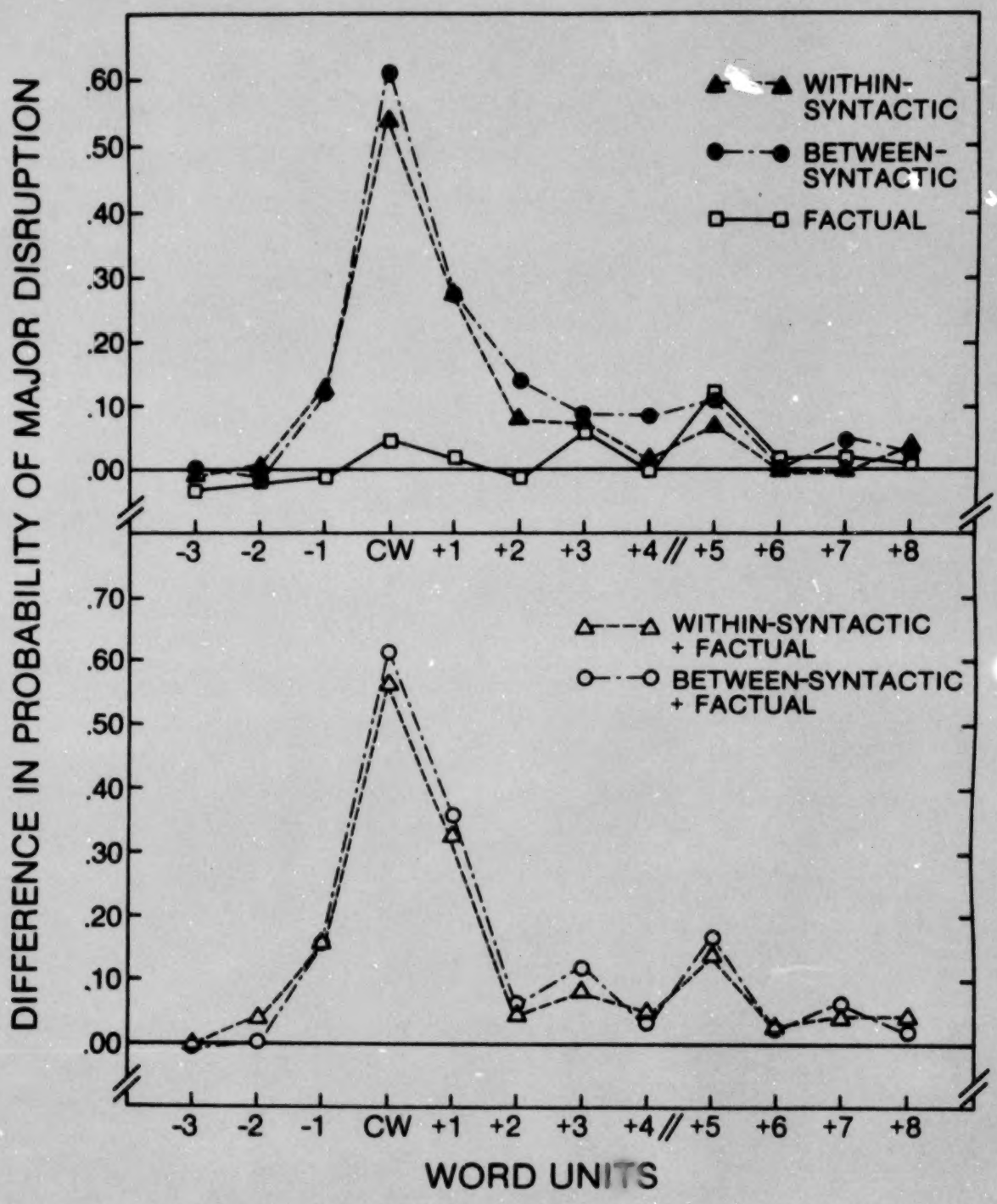

Figure 13. Experiment 7: Disruption curves for syntactic and factual violations.

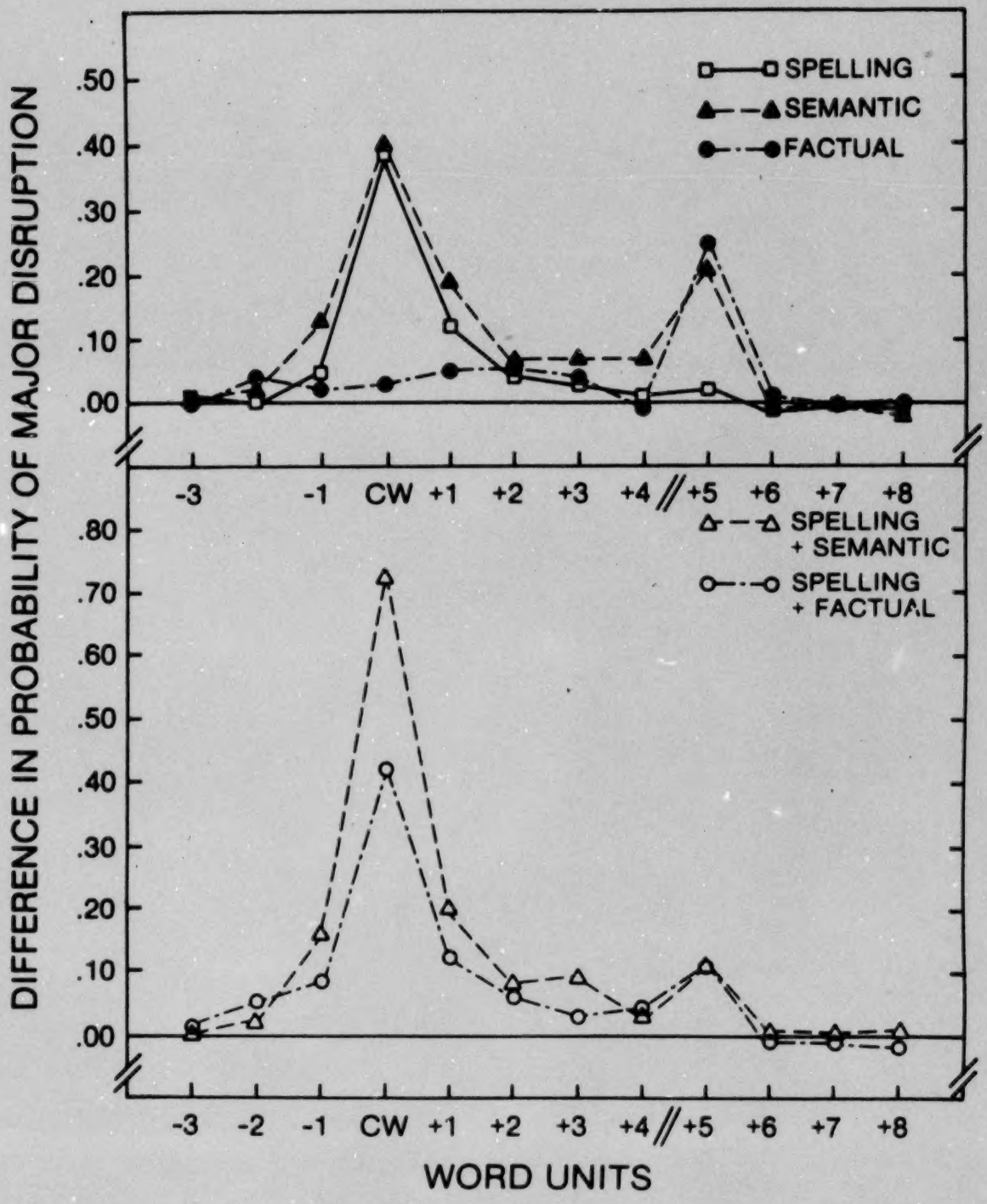

Figure 14. Experiment 8: Disruption curves for spelling, semantic, and factual violations.

Summarizing the last three experiments, lexical access and sentence comprehension components have been clearly identified in terms of what information each uses. Lexical access used lexical, spelling, syntactic, and semantic information and sentence comprehension used lexical, syntactic, semantic, and factual. Another processing component that used physical information may operate prior to lexical access. This component needs additional study to confirm its operating characteristics.

Experiment 9: Metaphor comprehension. A different approach to investigating how information is integrated between sentences is to study the comprehension of metaphors. Metaphors can be described in terms of a topic, a vehicle, and a ground. The topic is what the metaphor is about, the vehicle is the term used metaphorically, and the ground is the relation between the topic and vehicle. For example, in Some roads are snakes, the topic is "roads," the vehicle is "snakes," and the ground is a conceptual relation such as "long, curvy, and dangerous." In order to understand a metaphor the ground must be determined. This experiment (End, 1982; End & Danks, 1982) focused on whether comprehending the ground in one sentence would facilitate comprehending the ground in successive sentences.

The sentence materials consisted on eight groups of three metaphors having the same ground, e.g., Some roads are snakes, Some subways are worms, and Some rivers are ribbons. There also were 24 filler metaphors, 48 literal sentence, and 18 practice sentences. Each metaphor triad was always presented in sequence; the other sentences were ordered randomly. Sixty college students read each sentence separately rating it for difficulty of comprehension. The reading times were measured as well as the difficulty ratings (a three-point scale).

Both reading times and difficulty ratings showed a significant facilitation in the second and third positions in the triad: mean reading times were 3.53 sec., 3.15 sec., and 3.10 sec. and mean difficulty ratings were 1.67, 1.47, and 1.45, for the first, second, and third positions in the triad, respectively. Thus, priming the ground in the immediately preceding sentence facilitated comprehension of the following metaphors. The task did not require readers to relate successive sentences nor to judge difficulty of comprehension relative to preceding sentences. So they in principle could stop processing immediately after the sentence comprehension component had finished without integrating with the preceding sentences (discourse understanding). If sentence comprehension could function autonomously as posited by interpretive models, then there would have been no facilitation in the second and third metaphors of the triad. However, integration with the representations of preceding sentences (in this case, the grounds) occurred, as predicted by an interactive model, indicating that information from preceding sentences was used by and aided the sentence comprehension component.

Studies of Memory Representations

As has been argued earlier, the reading comprehension process is best studied by investigating on-line processing and not memory representations. However, in all of the experiments memory data were collected in the form of summaries, recalls, and recognition tests, depending on the particular

experiment. The purpose of these memory tests was to insure that readers attempted to comprehend the stories. Since the data are available, can they be used to confirm or disconfirm the processing results already discussed? Since the experimental focus was not on memory representations, the kinds of data collected varied somewhat from experiment to experiment. Sometimes readers were asked to write summaries after each quarter of the story, sometimes only at the end. Sometimes complete free recall was requested, sometimes only partial cued recall. Some of the experiments included recognition tests in addition to recall measures. The following is a representative summary of the memory results reporting only recall data.

In all cases, we focused on the three sentences around each critical word: the sentence "preceding" each critical word, the "critical" sentence containing each critical word, and the sentence "following." These sentences were analyzed into propositions for scoring. The proportions of propositions recalled for each sentence were the primary data. The only conditions reported here are those comparing factual violations (hence the interest in the preceding sentence) with control segments.

Experiments 4, 5, & 8. In Experiments 4A, 4B, and 4C, complete free recall was requested after the readers had finished each quarter of the story. Only factual violations and controls were included in the stories (except for case alternation in Experiment 4C). The proportion of propositions recalled for each of the three sentences is reported in the top row of Table 1. Recall of the preceding sentence was better with a factual violation than without. There were no significant effects with the critical and following sentences.

In Experiments 5 and 8, only partial recall was requested after readers had finished the entire story. Readers were given a copy of the story, exactly as they had read it, except that the three sentences around each critical word were replaced by blank lines. They were to fill in the missing sentences. Although semantic and spelling violations were included in the stories, only the factual violation results are reported. The mean proportion of propositions recalled for these two experiments is reported in the second and third rows of Table 1.

For both experiments, the preceding sentence was recalled better when there was a factual violation, a result that replicated Experiment 4. For Experiment 5, recall of the critical sentence was worse with a factual violation, and for Experiment 8, recall of the following sentence was worse with a factual violation. When readers encountered a factual violation in the critical sentence, they might have reviewed the preceding text in an attempt to resolve the factual inconsistency. This review must have been silent rereading, or just a mental rehearsal, since there was very little oral rereading. In any case, the review led to enhanced recall of the preceding sentence. The review evidently did not extend to the critical sentence since recall there was depressed, if anything. Recall of the following sentence may have been depressed by a continuing effort to resolve the factual inconsistency at the expense of reduced attention to the following sentence. The reduced recall of the critical and following sentences was not a strong finding, however. So additional experiments were conducted to clarify the results.

Table 1

Mean Proportion Propositions Recalled from the Preceding, Critical, and Following Sentences in Five Experiments

	Preceding		Critical		Following	
Experiment	Factual	Control	Factual	Control	Factual	Control
4	.104 *	.077	.101	.089	.043	.060
5	.103 *	.074	.030 *	.071	.048	.054
8	.130 *	.103	.099	.088	.069 *	.120
10	.160 *	.123	.118	.139	.101	.114
11	.224 *	.141	.177 *	.134	.110	.113
12	.533	.484	.401 *	.482	.606 *	.691

* Factual mean was significantly different from the control with $p < .05$ using subjects only in the error term.

Experiments 10 & 11. The next two experiments used only silent reading in order to extend the oral reading recall findings and to clarify the results for the critical and following sentences. In Experiments 10 and 11, groups of readers read the story silently at their own pace. The story included only factual violations and controls counterbalanced across two versions. After finishing the story, they completed the partial recall forms as in Experiments 5 and 8. The subjects were 31 college students in Experiment 10 and 42 college students in Experiment 11. In Experiment 11, 33 additional readers received the partial recall test one week after reading the story instead of immediately. Only the immediate recall group is reported here because the effects were much stronger with immediate recall and immediate recall was used in the other experiments.

The recall results are reported in the fourth and fifth rows of Table 1. In both experiments, recall of the preceding sentence was enhanced by a factual violation, as was recall of the critical sentence in Experiment 11, but not in Experiment 10. There was no significant effect of the factual violation on recall of the following sentence in either experiment. The silent reading results then supported the oral reading results for the preceding sentence, but not for the critical sentence. However, the different demands that oral and silent reading make on the reader might explain the differential results for the critical sentence. In oral reading, the reader was under implicit pressure to produce a continuous oral rendition. In silent reading, the reader could pause and reread the conflicting sentences without any pressure to continue. Thus, recall of both sentences would be enhanced because of the additional processing time spent on each. The absence of an effect for recall of the following sentence is consistent both with this explanation and with the decreased attention explanation for the oral reading case. Since in silent reading the reader could spend as much time as needed on the preceding and critical sentences before reading on, there would be no decreased attention to the following sentence.

Experiment 12. The final experiment in this series extended the investigation to listening. In this experiment, 48 college students listened to a tape recording of the story with factual violations and controls counterbalanced in two versions. The tape was stopped immediately after each following sentence. A copy of the story since the preceding critical segment was placed on an overhead projector. The three sentences of interest--preceding, critical, and following--were replaced with blank lines. The subjects then recalled the last three sentences they had heard using the preceding text as a cue, just as in the partial recall tests used in the reading experiments. Instead of scoring recall of all propositions, only recall of the most central proposition in each sentence was scored. The proportion of propositions recalled is presented in the last row of Table 1 for the three sentences.

The recall levels were much higher because of the very immediate recall after each critical segment and because only the central proposition was scored. There was no effect of the factual violation on recall of the preceding sentence, but recall of both the critical and following sentences was depressed by a factual violation. Although these results constituted a different pattern than obtained in the reading experiments, they were consistent with the explanations advanced there if the different demands

implicit in reading and listening tasks are considered (Danks & End, 1981). Listeners cannot review the physical text because the auditory input is transient. Hence, there was no effect of factual violations on the preceding sentence because when listeners heard it, they did not yet know that it would be involved in a factual inconsistency. The critical sentence was recognized as inconsistent with the preceding text and the difficulty listeners had integrating it with the preceding sentence hindered its recall. The following sentence was not recalled as well following a factual violation apparently because attention was devoted to resolving the factual inconsistency in the preceding and critical sentences. The recall of the following sentence was higher overall than recall of the preceding and critical sentences because the following sentence was the last one heard before the recall test was presented.

Although the results from these six experiments did not paint a complete picture of the fate of the memory representations, the results were reasonably consistent with each other across oral reading, silent reading, and listening situations. Comprehenders attempted to resolve the factual inconsistency through extra processing of the preceding and critical sentences, which in turn enhanced recall. When such reprocessing was not possible, recall tended to be depressed. Attempts to resolve the factual inconsistency apparently continued through the following sentence resulting in decreased recall of that sentence as well. On the whole, the recall results supported the interpretations of the oral reading experiments described in previous sections.

III. Differences Among Readers

A basic premise of interactive models is that processing mechanisms are a joint function of the information available, the cognitive demands of the situation, and the cognitive skills and strategies of the comprehender. This section focuses first on the cognitive skills of readers, in this case, children learning to read. Then it turns to the interaction of input structure and cognitive strategies in speakers of Polish, a language with a structure quite different from English. In the former case, children bring different cognitive skills to the reading situation than do skilled readers, so the component processes may operate differently. In the second case, the differences in information available to the reader of Polish may result in the development of different reading strategies from English readers as Polish readers attempt to make optimal use of the available information.

Children Learning to Read

What is the interaction of information sources as children learn to read? A reasonable first hypothesis is that children pay most attention to bottom-up information, because that is where most instruction is focused and that is where children have the most difficulty. As bottom-up processing becomes more automatic (LaBerge & Samuels, 1974), children are gradually able to use more abstract information for lexical access and meaning integration. Alternatively, children initially might be overly dependent on context and prior knowledge simply because they lack proficiency in processing bottom-up information. As they gain skill in decoding, bottom-up information would become relatively more useful to them, and the balance between bottom-up and top-down processing would shift.

Experiment 13. To investigate this question, the basic experimental paradigm used with skilled readers was adapted for children learning to read--second, fourth, and sixth graders. Stories were selected from primers one grade below the children's actual grade. The readabilities (Fry, 1968) of the stories were 1.6, 3.5, and 5.6 and the stories were 881, 1354, and 1617 words long. The stories were divided into four sections and five critical words were selected in each quarter. Lexical, syntactic, semantic, and factual violations were developed for each critical word following the same criteria as for the skilled readers. A portion of the second grade story is shown in Figure 15. The critical word big was replaced with bis for the lexical violation, with biggest for the syntactic, and with mad for the semantic. For the factual violation, fat was changed to little in the preceding sentence. Five versions of each story were constructed so that violations were counterbalanced across critical words and readers. There were 50 children tested at each grade level, 10 on each version of the story. In order to insure that the children paid some attention to comprehension, the children were asked three to four simple literal questions after reading each quarter of the story. The scoring of major disruptions was the same as described for skilled readers.

The disruption curves for the second, fourth, and sixth graders are shown in Figures 16, 17, and 18, respectively. A composite graph of comparable disruption curves from Experiments 2 and 3 for college readers

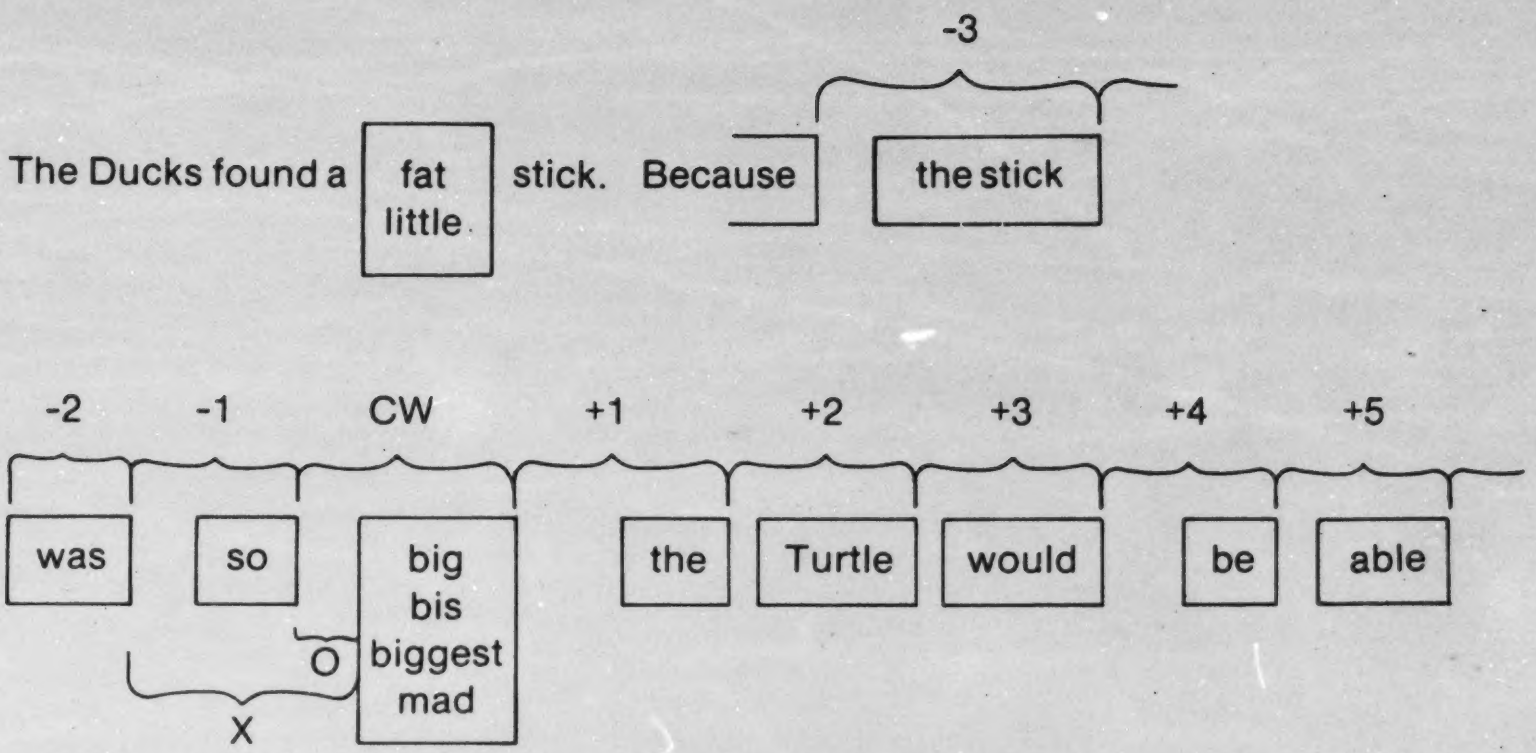

Figure 15. Experiment 13: A sample portion of text from the second grade story showing lexical, syntactic, semantic, and factual violations.

is shown in Figure 19. Although there were some differences across the three grades, the results were very similar. Lexical, syntactic, and semantic violations all produced their largest disruptions at the critical word and, to a lesser extent, at word unit +1. A few of the conditions were significantly different from the control as early as word units -2 or -1, namely, lexical in the sixth at -2, lexical in the second and fourth at -1, syntactic in the fourth and sixth at -1, and semantic in the second and fourth at -1. Likewise, there were a few significant effects at word units +2 and +3, namely, syntactic in the second at +2 and semantic in the fourth at +2 and +3. But the dominant effect was at and immediately after the critical word.

The factual violation produced small but significant disruptions in all three grades--at word unit +1 in the second and fourth grades and at the critical word in the sixth grade. Factual information may have been filling some useful role in lexical access for the sixth grades, but not for the second and fourth graders. The small size and the location of the children's factual disruptions indicated that resolving a factual inconsistency was more critical at sentence comprehension than at lexical access.

The major conclusion was that syntactic and semantic information influenced lexical access of the critical word as much as lexical information itself. The magnitudes of the disruptions were ordered from lexical violations producing the largest disruption, followed closely by syntactic and semantic violations. Perhaps these children were well along the way to becoming skilled readers, so that bottom-up processing was relatively automatic, thus permitting top-down processes to operate. Their reading rates indicated that this was not the case, however. Estimating reading rates from the control condition, the second graders read at 123 syllables per minute, fourth graders at 161 syllables per minute, sixth graders at 181 syllables per minute, and college students at 270 syllables per minute. The children's reading on the whole was not as fluent as that of skilled readers; they read more slowly and haltingly.

In a comparison of the children's results with those of skilled readers, there were no major differences as a function of skill level. Top-down factual information might be used earlier as readers gain skill, i.e., the factual disruption was significant at word unit -1 for second and fourth graders, but at the critical word for sixth graders. However, in college students the factual disruption reverted to its post-critical word position, so no strong theoretical conclusions can be drawn from the shift in the sixth graders. These particular children may have been more highly skilled than one would expect from the grade level (standardized reading test scores were not available), but still they were not reading at adult levels. The use of relatively easy, grade-appropriate stories may have allowed the children to use more skilled reading strategies. Also, some of the children's inefficiencies may have been masked by their slow reading rates. Whatever the reasons, there were no substantial differences in the pattern of results across grades. Thus, the operating characteristics of the processing components and the processing strategies apparently were the same across wide differences in reading skill. Some minor processing differences may have existed, but the dominant impression was one of constancy.

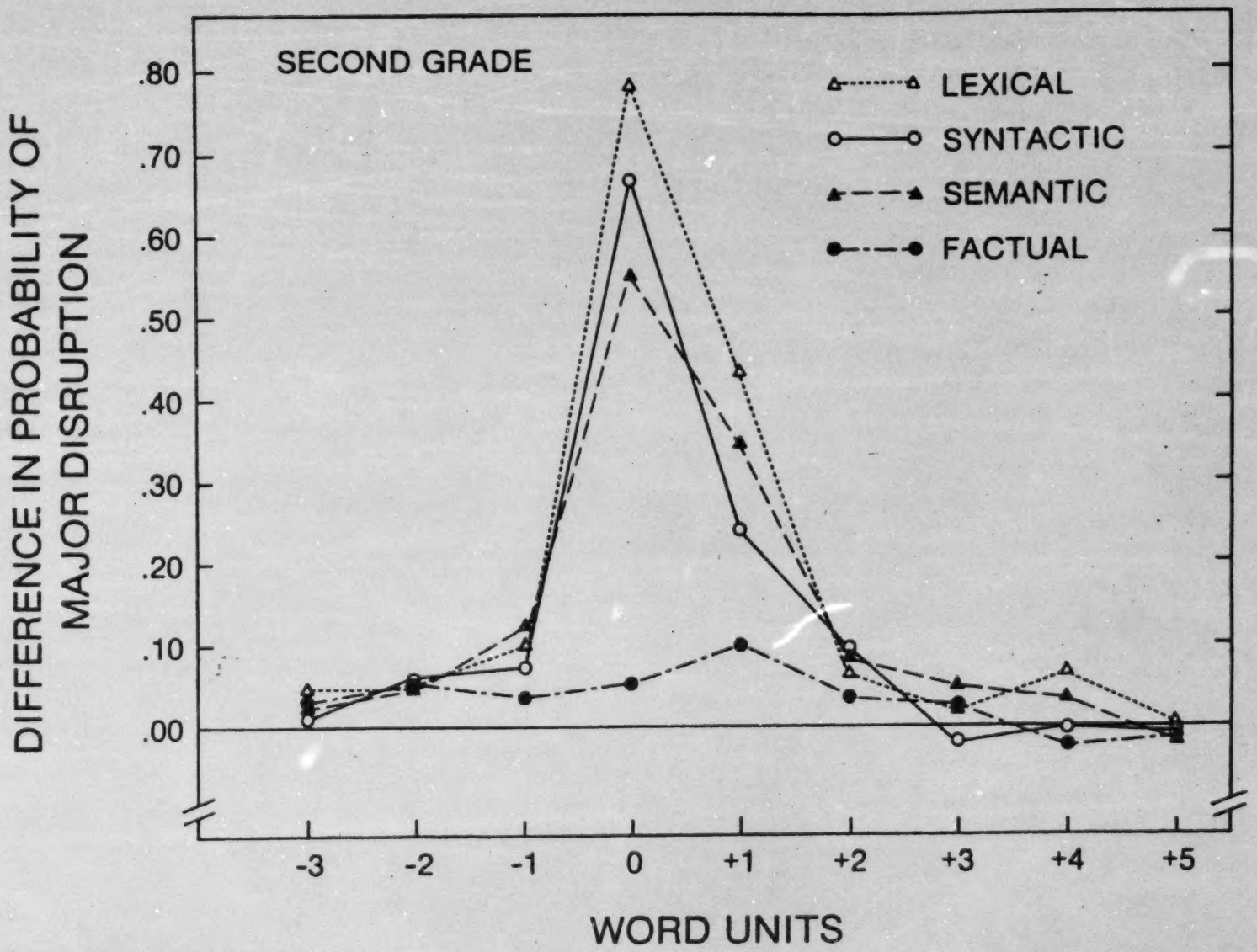

Figure 16. Experiment 13: Second graders' disruption curves for lexical, syntactic, semantic, and factual violations.

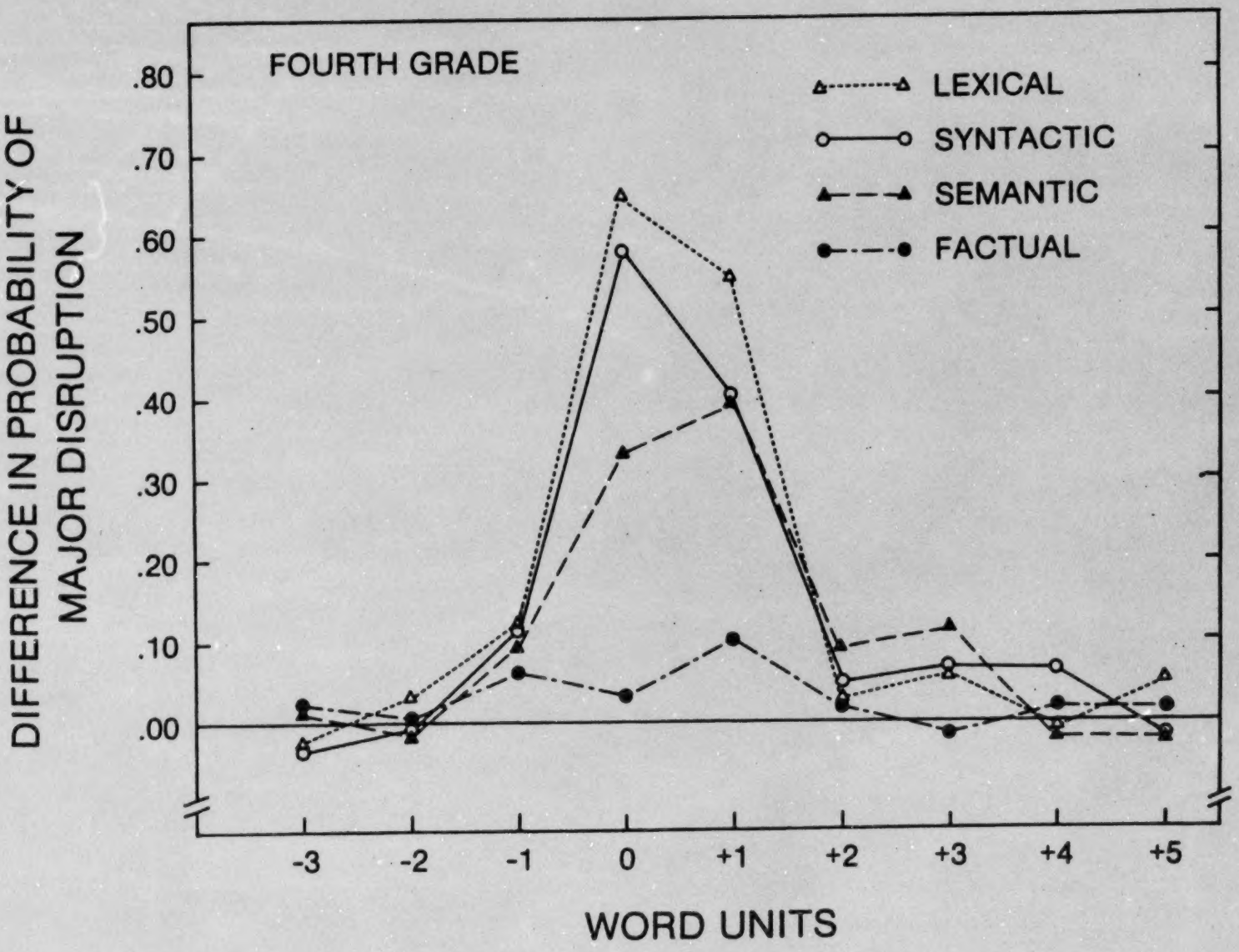

Figure 17. Experiment 13: Fourth graders' disruption curves for lexical, syntactic, semantic, and factual violations.

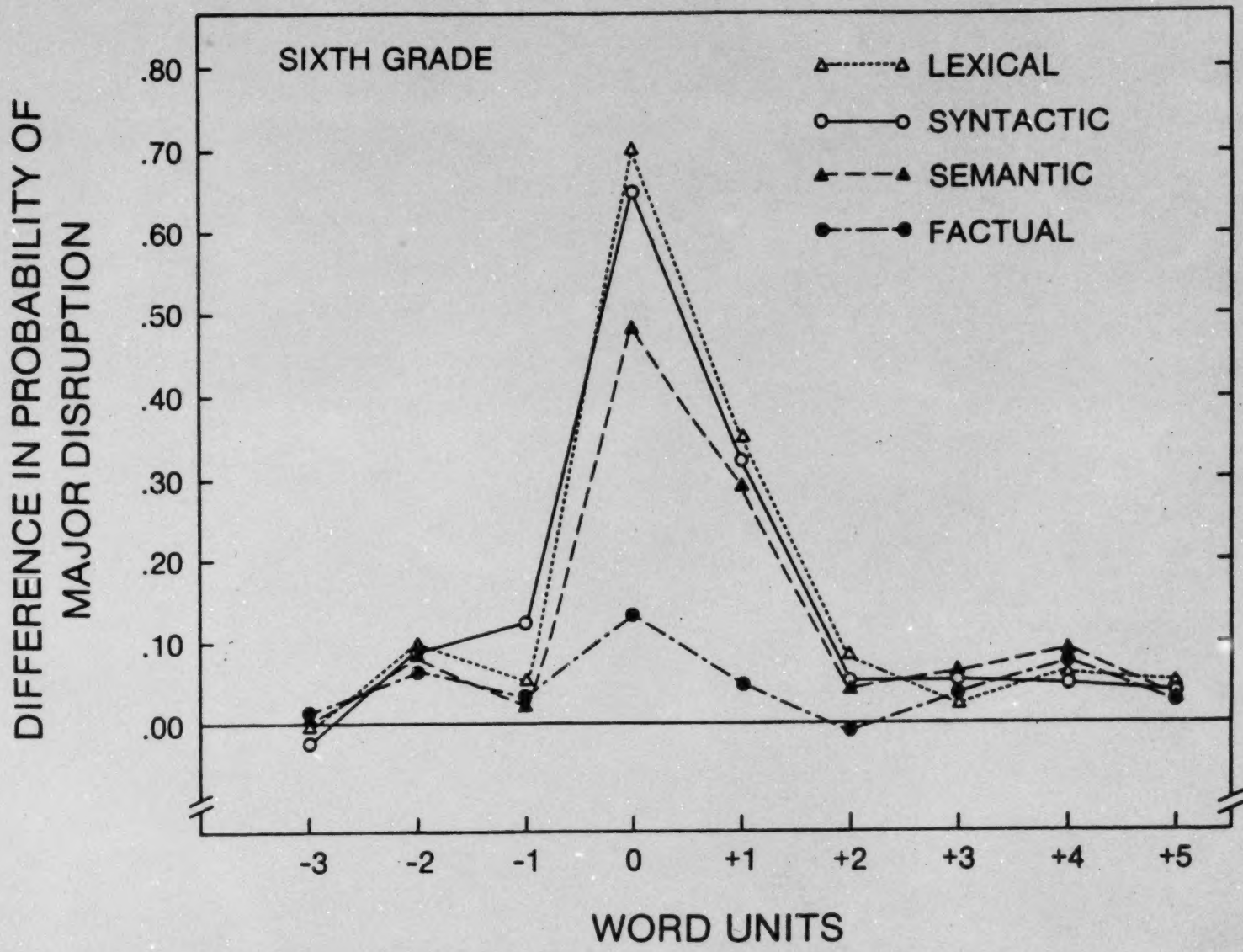

Figure 18. Experiment 13: Sixth graders' disruption curves for lexical, syntactic, semantic, and factual violations.

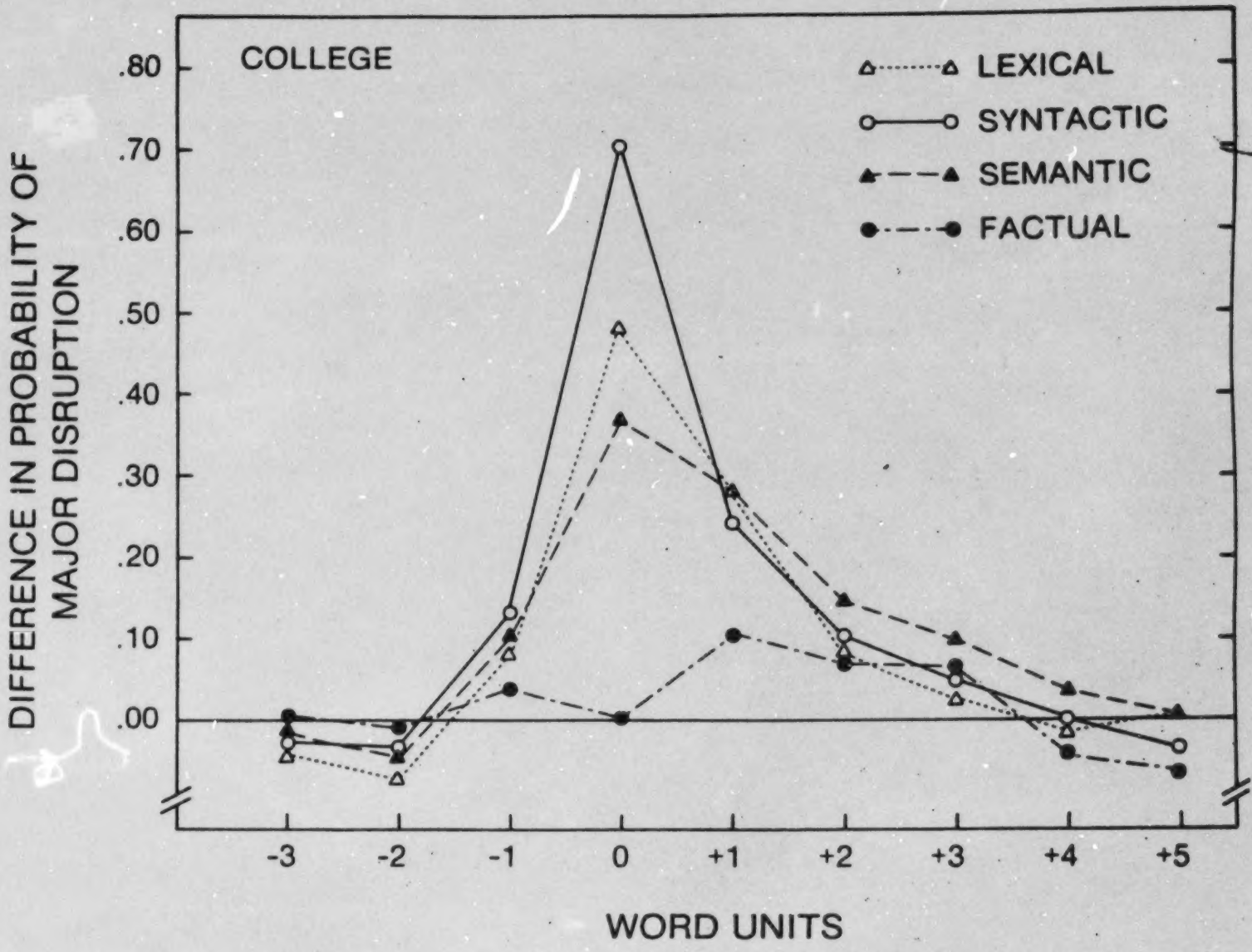

Figure 19. College student composite disruption curves for lexical, syntactic, semantic, and factual violations.

Processing Strategies in Polish and English Readers

The interactive approach posits that comprehenders (listeners and readers) adapt their comprehension strategies to the situation. The flexibility of language processing is represented in the interaction between the cognitive demands of the situation and the cognitive skills of the comprehender. Differences in language structure can affect these cognitive demands and, thus, the structure of the comprehension process. Some languages, like English, encode syntactic information primarily in terms of word order. Other languages, like Polish, Russian, and Finnish, encode most of the syntactic information in suffixes. One would expect then that comprehenders of these languages would be more attentive to word endings than would English language comprehenders. The primary purpose of the next experiment was to explore what effect such differences in language structure would have on reading comprehension processes. Several of the conditions previously described for English-language readers were replicated with Polish readers.

Polish is a Slavic language that differs in many ways from English. In addition to obvious differences in pronunciation, spelling, and vocabulary, Polish and English differ in their syntactic structure. In English syntactic information is indicated primarily by how words are ordered in sentences. The position of a given word in relation to other words in a phrase or clause indicates how the word functions syntactically. In Polish the syntactic function is marked by the morphological structure of the word itself, not by its sequential relation to other words. Most words have specific suffixes that indicate the part of speech. Additionally, within each part of speech, inflections organized in declensions and conjugations further specify syntactic function by differentiating among genders, numbers, tenses, and cases. For example, in Alicja dała książkę przyjacielowi, "Alice gave a book to a friend," the -a suffix on Alicja indicates feminine, singular, nominative case, the -ła on dała indicates past, third-person singular, feminine subject, the -ę on książkę indicates feminine, singular, accusative case, and the -owi on przyjacielowi indicates masculine, singular, dative case. If the friend had been a girl, then the ending would have been -ce, przyjaciółce (not stem variation as well).

Both Polish and English are subject-verb-object (SVO) languages, but in Polish the basic SVO word order can be altered quite readily for sylistic and pragmatic purposes, such as to fulfill the given-new contract. If a speaker wished to emphasize the friend in the above example, przyjacielowi could be moved to the first position in the sentence with no other change. Like wise, any other word in the sentence could be placed in first position, and almost any other ordering of the four words is also possible. The literal meaning of the sentence would remain the same; only the pragmatic emphasis would change. In English, of course, very few changes in word order are possible that do not also change the meaning of the sentence. But English has very few inflectional endings that indicate syntactic function.

Thus, we expected that Polish readers have developed reading strategies of attending not only to the semantic content of each word, as an English reader would, but also to the word ending. English readers would pay

relatively less attention to the word endings and relatively more to their position in the sentence. Introducing a syntactic violation by changing the ending of a word so that it is a different part of speech, we expected a relatively larger disruption of oral reading performance in Polish than in English. We also expected that the spread of disruption in English readers would be relatively wider than in Polish since English readers would attempt to use contextual information to resolve the violations. Polsih readers would have relatively narrower patterns of disruptions because they focus more on isolated words than do English readers. So Polish readers would have a more focused strategy, while English readers would have a more diffused strategy.

Experiment 14. The story about the injured girl was translated into Polish with some minor adjustments to make it culturally appropriate for Polish readers. A portion of the story surrounding one of the critical words, potrącona, "injured," is shown in both Polish and English in Figure 20. Lexical, between-syntactic, within-syntactic, semantic, syntactic + semantic, and factual violations were introduced. For the lexical violation, a pronounceable (in Polish) nonword, e.g., pomerana, replaced the critical word. For the between-syntactic violation, the word ending was changed such that the part of speech changed, e.g., the past participle potrącona was changed to potrącenie, "injury," a noun. For the within-syntactic violation, the word endings were changed within the same part of speech, but gender, number, case, and/or tense relations were violated, e.g., the verb participle potrącona, which marks feminine gender, was altered to potrącony, still a verb participle, but one that marks masculine gender. For the semantic violation, a semantically anomalous word, posadzona, "planted," replaced the critical word. Both syntactic and semantic information were distorted by replacing the critical word with one that was the incorrect part of speech and which was semantically anomalous as well, e.g., potrącona was replaced with posadzenie, "the act of planting." For the factual violation, the preceding sentence was changed to create a factual inconsistency, e.g., słaba, "weak," was changed to silna, "strong."

These conditions were combined in two experiments in Polish. In Experiment 14A, lexical, within-syntactic, syntactic + semantic, and control were manipulated and in Experiment 14B, between-syntactic, semantic, factual, and control were manipulated. The 40 subjects in each Polish experiment were students at the University of Warsaw. The procedure was identical to that described for the modal experiment. The primary dependent variable was the production time for each of the word units before and after the critical word as well as the time for the critical word itself. The reliabilities between experimenters for the measurement of production times were .99 and .92 for Experiments 14A and 14B, respectively.

The disruption curves (mean differences in production times between experimental violations and control) are presented in Figures 21, 22, 23, and 24. English-language results are included in the figures for comparison. Polish readers were disrupted earlier (word unit -1) than were English readers (at the critical word) by the between-syntactic violation. This result was as expected based on the fact that Polish suffixes are more informative than are English. Polish readers apparently attended

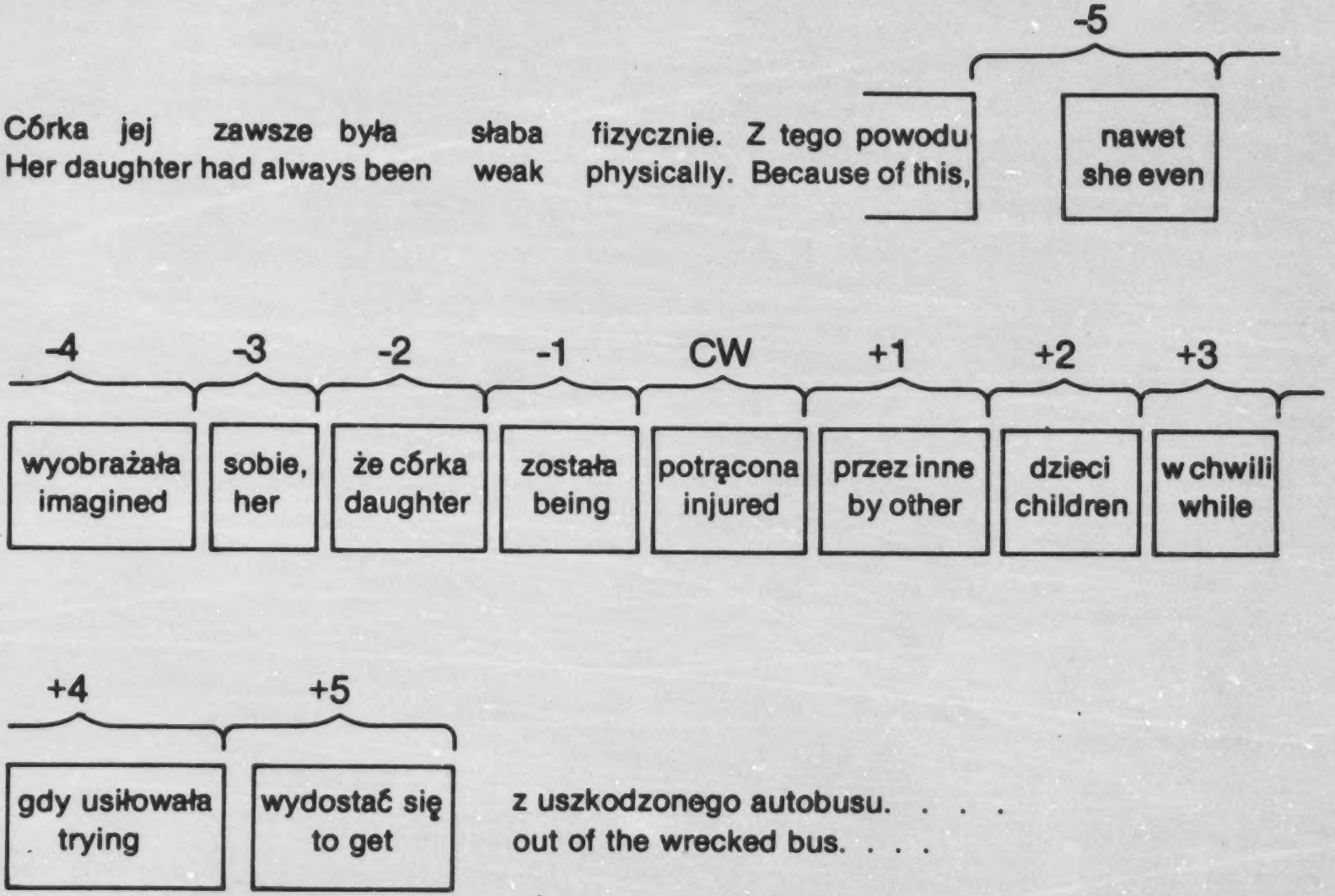

Figure 20. Experiment 14: A sample portion of the Polish and English story around a critical word.

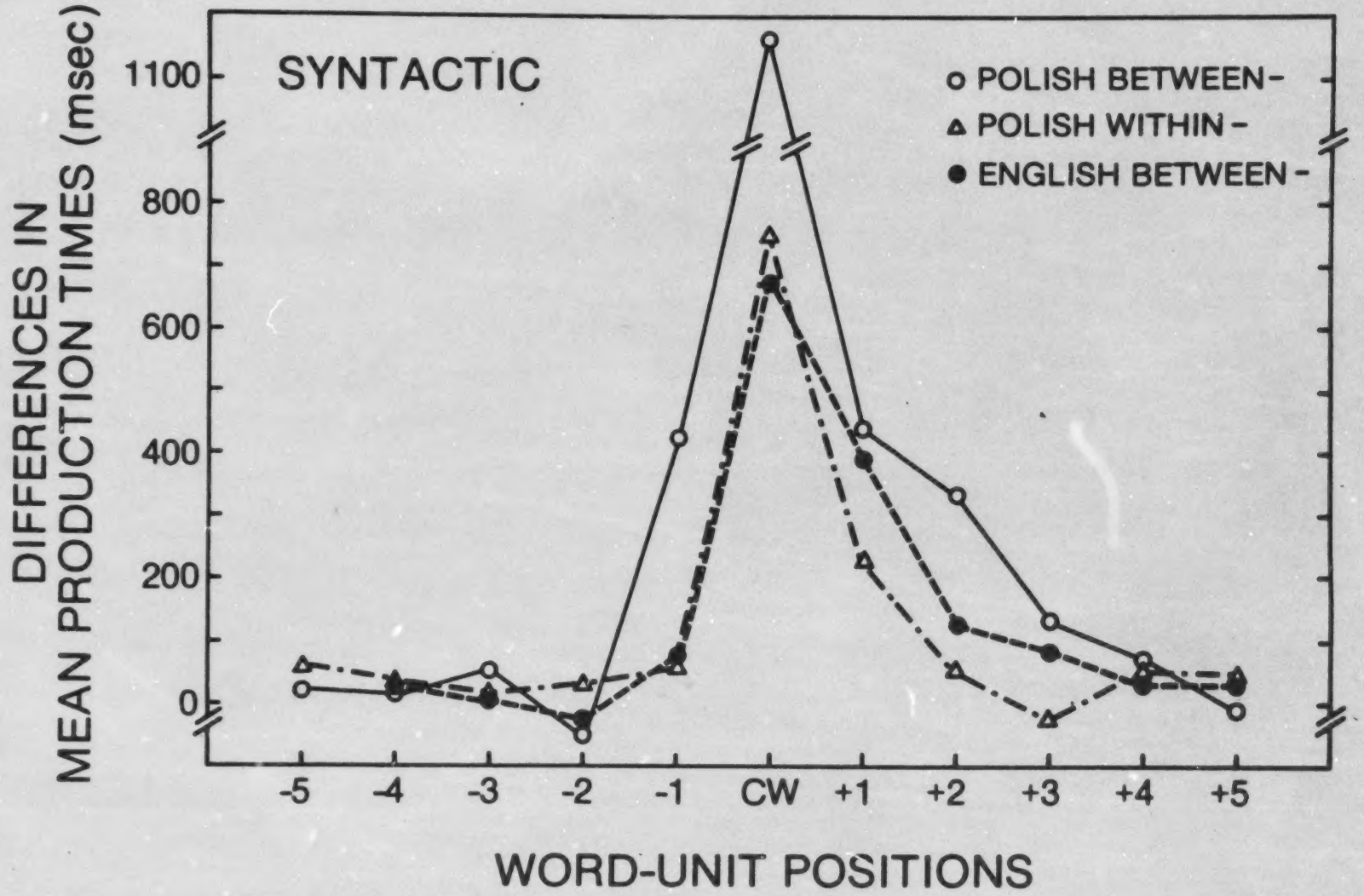

Figure 21. Experiment 14: Polish and English disruption curves for syntactic violations.

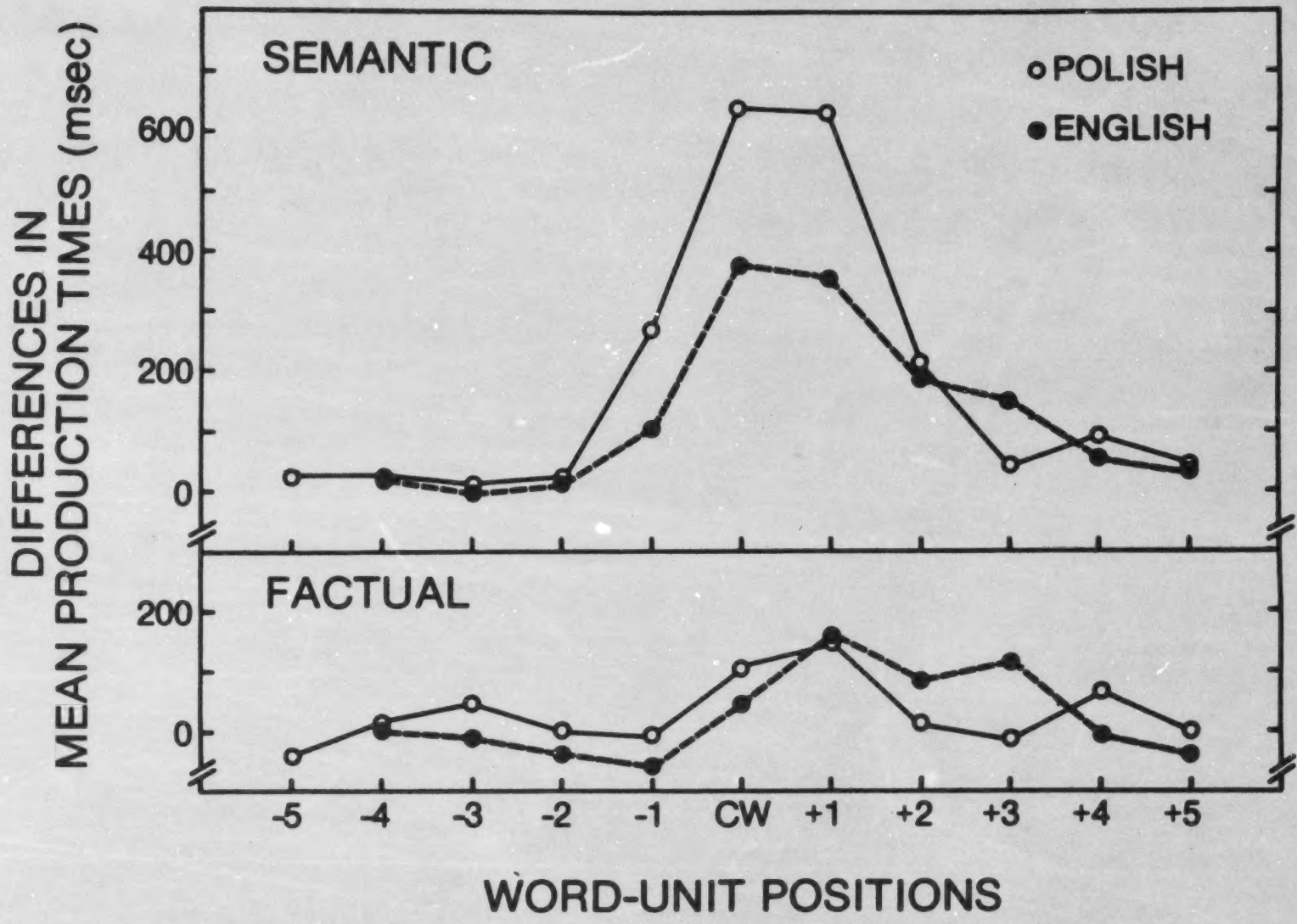

Figure 22. Experiment 14: Polish and English disruption curves for semantic and factual violations.

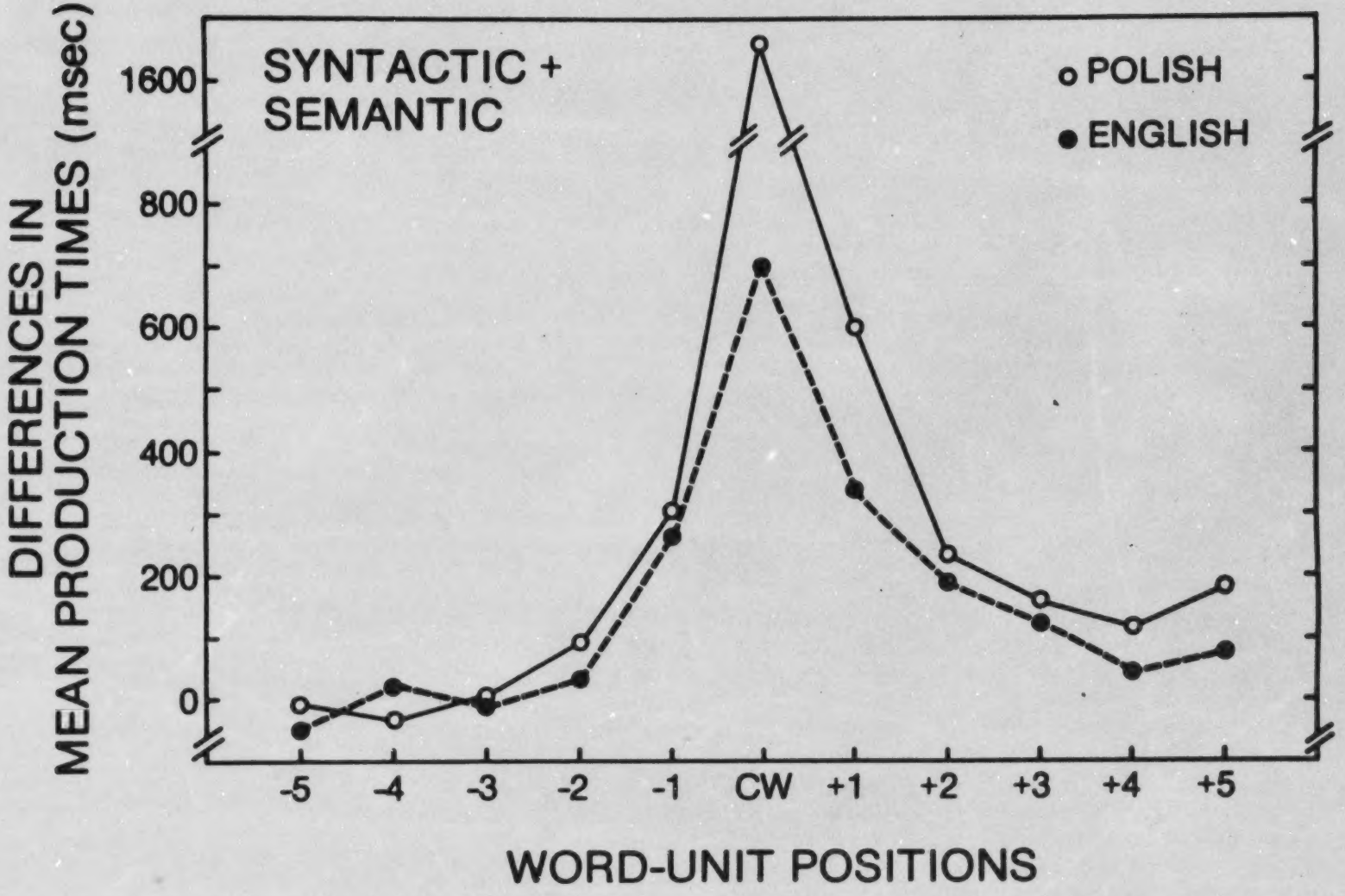

Figure 23. Experiment 14: Polish and English disruption curves for the syntactic + semantic violation.

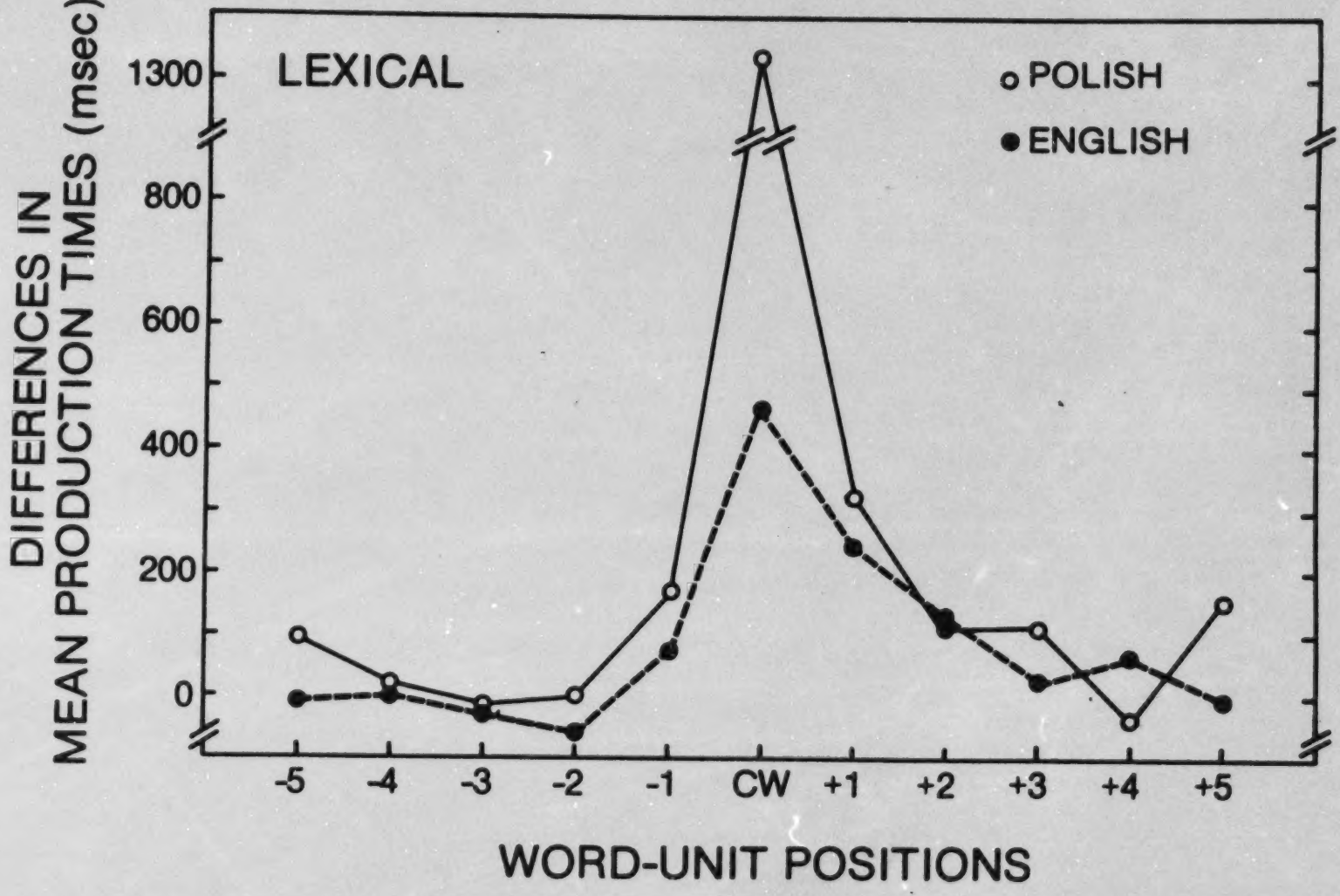

Figure 24. Experiment 14: Polish and English disruption curves for the lexical violation.

more to the word endings, so their reading comprehension processes were disrupted more by a violation present in those endings. In Polish, only 9% of the oral reading errors were substitutions of any sort, including restorations, whereas in English 54% were restorations. If Polish readers were attending closely to the ends of words, then they would be more likely to notice the syntactic violations before top-down contextual information could restore the original critical word. The Polish within-syntactic disruption began only at the critical word. The within-syntactic violation violated fewer linguistic distinctions than did the between-syntactic. Since Polish readers needed to make fewer repairs to determine what was meant by the sentence, we expected that the within-syntactic violation would be less disruptive. English readers apparently treated all syntactic violations more or less equivalently, whereas Polish readers were sensitive to the degree of linguistic violation.

The pattern of the semantic disruptions (see Figure 22) were nearly the same in Polish and English (although the English missed being significant at word-unit -1 by 9 msec.), but the English disruption continued for one word-unit longer. The Polish curve was higher than the English, but the shapes were quite similar. The slightly greater breadth of the English disruption supported the linguistic analysis that English readers were more dependent on linguistic context to determine the sense of a sentence, whereas Polish readers focused a bit more on individual words.

Both Polish and English syntactic + semantic violations produced significant differences from the control conditions beginning at word-unit -1 with peaks at the critical word (see Figure 23). The English disruption was significant through word-unit +3, but the Polish was significant only through word-unit +2. The Polish curve was not as broad as the English, similar to the syntactic curves, supporting the conclusion that Polish readers were more focused on individual words and were sensitive to word endings.

Both Polish and English disruption curves from the lexical violation (see Figure 24) were significantly different from the control beginning at the critical word and continuing to word unit +1 in Polish and to word-unit +2 in English. The curve was a bit sharper, or more peaked, in Polish than in English. As with the other cases of sharpening, we attribute this difference to the fact that Polish words are more self-contained in marking syntactic information, so the Polish reader can focus on individual words more directly.

The factual disruption in Polish was significantly different from the control when averaged across all word-unit positions. However, it was not significantly different at any single word-unit position although the increase at word-unit +1 missed being significant by only 15 msec. (see Figure 22). The fact that the English curve continued longer than the Polish reflects a strategy of English readers in which they attempt to use information following the critical word to attempt to resolve the factual inconsistency more than do Polish readers.

Based on these results we can identify two complementary reading strategies--a focused strategy and a diffused strategy. Although a focused strategy was used more by Polish readers and a diffused by English,

the use of each strategy was controlled by more than just language differences. With a focused strategy, the reader attends to a relatively narrow portion of the text, perhaps only a few letters. The reader would adopt such a strategy in situations where information is concentrated in a relatively narrow portion of the text. In Polish, syntactic information is so concentrated in the letters at the end of each word. While learning to read, Polish readers would develop a focused strategy because most syntactic information is concentrated. This strategy is not absolute nor rigidly used all of the time, but rather is a habit adopted for its heuristic value. English readers would tend not to use such a strategy because linguistic information is distributed more broadly in English text, but in appropriate circumstances, English readers might find a focused strategy valuable.

With a diffused strategy, in contrast, the reader assimilates information from a much broader portion of the text, perhaps spanning several eye fixations. Such a strategy would be functional when the information in the text is distributed over several words. Such is the case with English syntax. It is based primarily on the ordering of word classes. So in English, in contrast to Polish, processing syntactic information would be facilitated by a diffused strategy.

The largest differences between the Polish and English results were from the syntactic violations. Polish readers were very sensitive to the violation of syntactic information. There was a higher between-syntactic peak in Polish, fewer restorations of the critical word, and a sensitivity to whether between- or within-syntactic information was violated. Polish readers attended more closely to the word endings and the information encoded there, reflecting their general adoption of a focused strategy. English readers in contrast showed a more diffused strategy.

Determining the meaning of a sentence requires the integration of word meanings. Since several words have to be accessed before such integration can begin, a diffused strategy is functional for processing semantic information. This is the case for both Polish and English readers because the distribution of semantic information is quite similar, especially with the close translation of the story used in this experiment. The semantic violation should reveal the diffused strategy in both Polish and English readers, and it did because the shapes of the curves were similar. Although the peak of the Polish disruption was higher than in English, more striking was the similarity of the flattened peaks on both curves (see Figure 22).

We have emphasized the differences between Polish and English in the discussion, but one should not overlook the similarities in the two sets of results. All violations produced disruptions in both languages. Furthermore, the general shapes of the disruption curves were quite similar, e.g., the flattened peaks of the semantic disruptions. Within each language, the ordering of the magnitudes of the disruptions, from syntactic + semantic being the largest to factual being the smallest, was virtually identical. These general similarities then provide support for the general interactive model of reading comprehension (Danks et al., in press; Danks & Hill, 1981) using Polish, a language that represents syntactic information quite differently than English. The linguistic

differences led to predictable differences in results based on the model.

A central property of this model is that readers use information as soon as it becomes available to construct a representation of the text. In Polish and English, syntactic information becomes available at different times because of how it is encoded. So Polish and English present different sort of problems for readers. They make different demands on the cognitive processing system. The differences in processing are explicable in terms of the differences in cognitive demands. Polish readers did not employ an exclusively focused strategy nor did English readers employ an exclusively diffused one, but all readers adapted their reading strategies to the information available. The differences represent an example of the flexibility of processing strategies. The basic structure of the reading process appeared to be quite similar for Polish and English readers, involving lexical access, sentence comprehension, and discourse understanding components. However, how these processes operated depended on the information available to the components and the form that the information took in print.

IV. Differences Across Reading Tasks

Another facet of interactive models is the provision for processing flexibility from task to task. Perhaps readers develop different sorts of reading strategies to meet the typical demands that they encounter in most reading situations, but when faced with more novel demands, or when asked to shift from one task to another, they are unable to adapt. Their reading processes may not be sufficiently flexible to adapt to immediate demands. On the other hand, readers may be able to shift processing strategies quite readily to meet changing task demands, so long-term adaptations would result from the ability to make short-term shifts. A second question is whether children are as flexible as skilled adult readers in adapting their reading processes to meet task demands. Perhaps skilled adult readers have learned how to be adaptable or perhaps they have gained sufficient control over their reading processes to adapt them, whereas children learning to read may not have developed such control. In the first part of this section, two experiments are reported, one with skilled adult readers and another with second graders, in which task demands are varied between an emphasis on pronunciation and an emphasis on comprehension. In the second part, the metacognitive task of comprehension monitoring is considered in both children and adult readers.

Pronunciation and Comprehension Tasks

What changes in processing strategies, and thence in the pattern of disruptions are produced by the introduction of task demands similar to those imposed on children in typical classrooms? Teachers supervising children in round-robin reading tend to focus attention on the oral rendition by correcting any deviations from the text and by giving relatively little attention to whether children understand what they are reading (Durkin, 1978-79). Teachers frequently correct the children for mispronunciations and other sorts of oral reading errors, but there is little discussion of what the story means and how it can be interpreted. Typically, the teacher and the other children are following the text, so that they know immediately if the oral reader makes a mistake. This situation produces considerable pressure on the child to be accurate in his oral productions and not to be too concerned about comprehending the meaning. Pehrsson (1974) tested fifth graders under such conditions. When the teacher focused on correct decoding and oral production, reading rate and comprehension decreased. Conversely, if the children were permitted to read without interruption and if they had to retell what they had read, comprehension increased. So an emphasis on pronunciation, as opposed to an emphasis on comprehension, altered the children's reading processes.

If readers expect to be tested on their knowledge of the content of a passage (a comprehension task demand), then the readers will process the passage to the most abstract level of analysis that they are capable of. In terms of the experimental rationale used here, sentence comprehension, as reflected in semantic and factual disruptions, would show increased emphasis. Lexical access would still be important for constructing a meaningful representation, so it would not be diminished, but neither would it be emphasized. However, if readers are being evaluated (either implicitly or explicitly) solely on the quality of their oral productions

(a pronunciation task demand), then they may focus their attention on lower levels of processing, such as lexical access, that are needed to provide articulatory information, and on syntactic information needed for proper prosody, thereby ignoring sentence comprehension. Thus, with a pronunciation emphasis, spelling and syntactic violations would show increased disruptions, while factual would not. Semantic violations would show increases at the critical word, but not at the clause boundary.

Experiment 15. This experiment focused on evaluating the effects of pronunciation and comprehension task demands on the reading processes of skilled adult readers. Experiment 8, which used spelling, semantic, factual, spelling + semantic, and spelling + factual violations, was replicated with two new groups of 60 college student readers except for the introduction of task demands. All subjects were given $5.00 at the start of the experiment. Readers in the pronunciation-emphasis group were told that they were to read with clear, accurate, precise pronunciation, as if they were making a tape recording for the blind. To provide incentive, they were told that they would lose 5¢ for each oral reading error, such as substitutions, repetitions, and mispronunciations, and that they could keep any money they had left at the end. They then were given a practice story (as were the readers in Experiment 8) that did not contain any violations. The experimenter kept track of oral reading errors according to a very strict criterion such that readers lost about $1.00 on the practice story. The pronunciation instructions were reemphasized and then the readers were given the experimental story with violations. At the end they were given a partial cued recall test over the experimental story.

The readers in the comprehension-emphasis group were told that we were interested in reading comprehension. "If we don't understand what we're reading, there's not much sense in reading at all." They were told to read for comprehension and that they would be given a comprehension test when they finished. For each question missed on the comprehension test, they would lost 5¢. They then were given the practice story followed by a very difficult comprehension test on literal information. The questions were sufficiently difficult that most readers lost about $1.00 on the practice test. After reemphasizing the comprehension task, the readers were given the experimental story followed by a partial cued recall test. All readers lost more than $1.00 on the experimental story, but all were paid $3.00 for their services in addition to the normal points for participating in the introductory psychology subject pool. All other procedures, scoring, and analyses were identical to Experiment 8.

The resulting disruption curves for the pronunciation and comprehension groups are shown in Figures 25 and 26, respectively. In comparison with the results of Experiment 8 (cf. Figure 14, p. 29), the general shapes of the disruption curves appear reasonably similar. However, there were several differences that were consistent with the rationale. In the pronunciation group, the relative size of the spelling disruption was enhanced. In Experiment 8, the semantic disruption was significantly larger than the spelling at word unit -1 and there was no difference at the critical word. In this experiment, the pronunciation group produced a significantly larger spelling disruption at the critical word and the difference at word unit -1 disappeared. Thus, spelling information played a more important role in lexical access when pronunciation was emphasized than when it

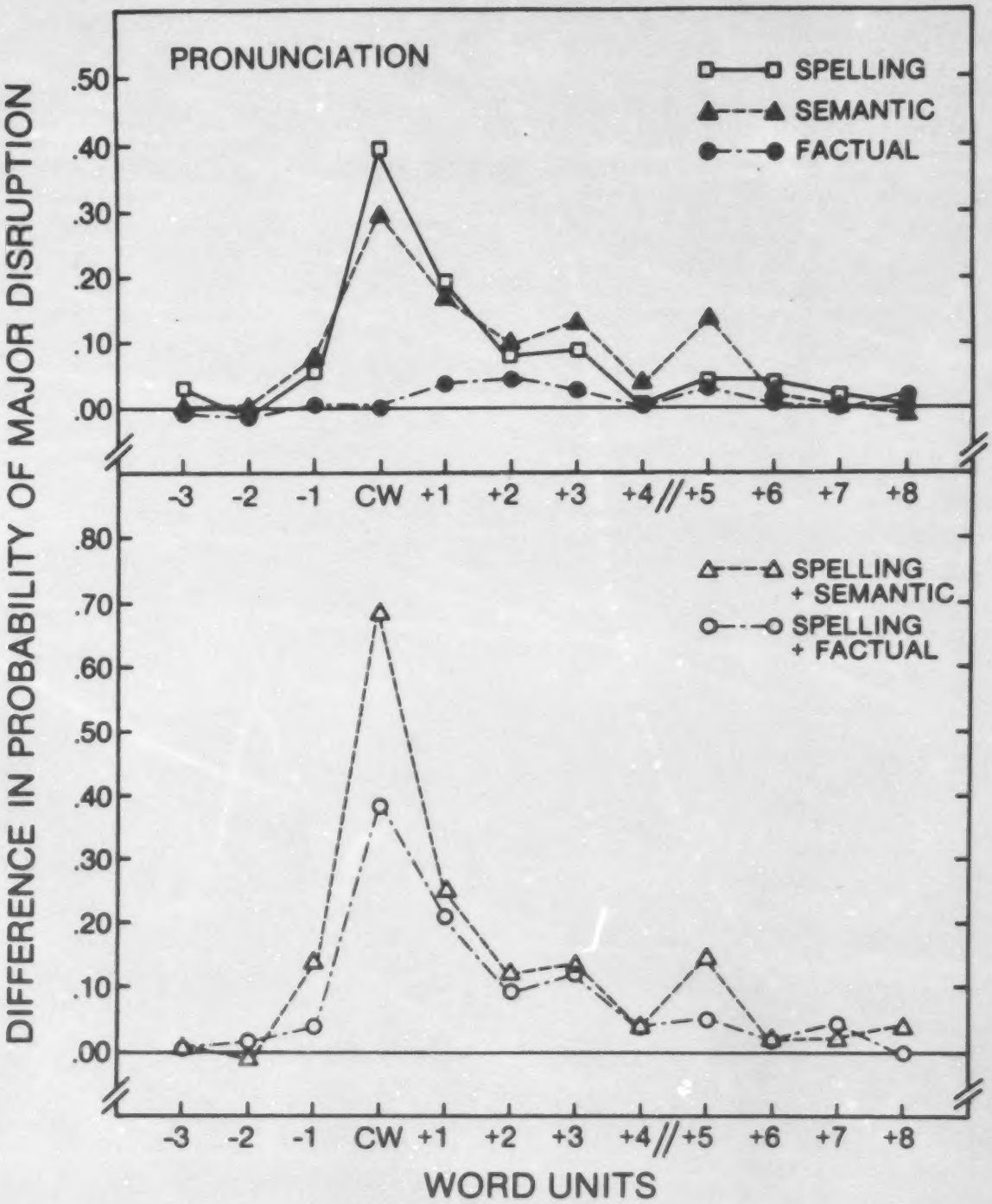

Figure 25. Experiment 15: Disruption curves for the pronunciation-emphasis group.

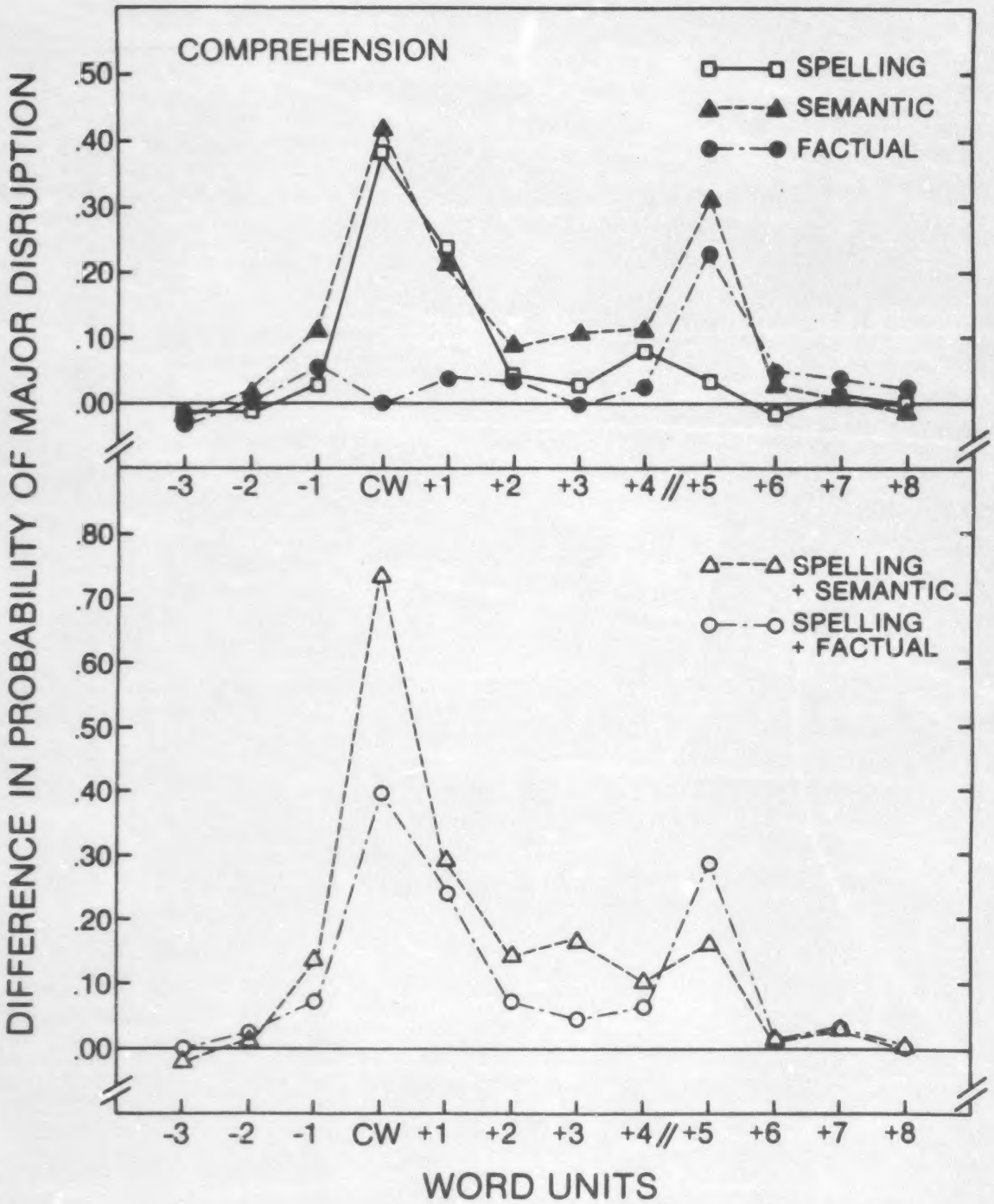

Figure 26. Experiment 15: Disruption curves for the comprehension-emphasis group.

was not. At the clause boundary, the factual disruption was eliminated in the pronunciation group, both when factual information was violated alone (upper panel) and when it was combined with misspelling (lower panel). So when pronunciation was emphasized, the factual information was not processed, at least not enough to produce any disruptions, only a flat curve paralleling the control condition.

An emphasis on comprehension did not affect the lexical access component. In comparison with Experiment 8, the comprehension group did not yield any differences at or near the critical word. The disruptions from all violations were quite similar in both groups, indicating that lexical access was necessary for comprehension. However, a comprehension emphasis did produce effects later in the process. At the clause boundary (word unit +5), the semantic and the spelling + factual disruptions were enhanced relative to Experiment 8. Especially interesting was the result that the spelling + semantic violation produced a larger disruption than the spelling + factual at the clause boundary in the pronunciation group, but the relationship was reversed in the comprehension group, indicating the increased importance of the factual information to sentence comprehension.

In summary, these results, especially the comparison of the pronunciation and comprehension groups, support the claim of interactive models that the reading comprehension process is quite flexible and adaptable to the immediate demands of the reading situation. When there was an emphasis on pronunciation, the less abstract information sources, such as spelling, were more important and had an effect on lexical access but not on sentence comprehension. In contrast, when comprehension was emphasized, the more abstract information sources, such as semantic and factual information, produced larger effects, primarily at the clause boundary, indicating involvement of the sentence comprehension component.

Experiment 16. This experiment investigated whether children's reading comprehension processes show the same flexibility as did skilled adult readers'. The pronunciation and comprehension emphases were induced in two groups of second grade readers. One group received pronunciation-emphasis instructions and a second received instructions that emphasized comprehension. In the pronunciation-emphasis condition, the children were instructed to read the story very carefully and accurately as if they were reading to a blind child. No mention was made of comprehension. During the reading of a practice story, a hypercritical experimenter corrected every pronunciation error no matter how small. Then the readers was presented with the experimental story. Although the experimenter did not interrupt or correct the children while they were reading the experimental story, she did reemphasize accurate oral production during short breaks between sections of the story.

In the comprehension-emphasis condition, the children were told to pay attention to the content of the story because they would be asked questions about the story when they finished. The reading aloud was mentioned almost as an afterthought. While reading the practice story, they were not corrected in any way. After they finished, they were asked some very difficult questions about the story. The experimenter pressed them for answers and urged them to pay more attention to what they were reading. The children were required to go back to the story and find

the answer to any questions that they could not answer. The childern then were given the experimental story and during the breaks the comprehension orientation was reemphasized.

In addition to the task emphases, the difficulty of the story also was manipulated. Half of the readers in each task group were presented with the story used with the second graders in Experiment 13 (readability = 1.6). This story was relatively easy for the second grade readers. The other half of each group was given the fourth-grade story from Experiment 13 (readability = 3.5). This story was relatively difficult, though not frustrating, for second graders. The practice story (readability = 1.6) was the same for all groups. Twenty-five second graders were tested in each of the four conditions defined by the interaction of task emphasis and text difficulty. Exactly the same stories were used as in Experiment 13, including lexical, syntactic, semantic, and factual violations and controls. The scoring and analyses of the protocols were the same as in Experiment 13.

The disruption curves for the four groups are presented in Figures 27, 28, 29, and 30. The dominant impression that one receives from the four figures is one of similarity. There were no salient differences in the patterns of disruptions resulting from the task emphasis and text difficulty manipulations. The curves were somewhat more variable than those from Experiment 13 because they were based on half as many readers.

In all conditions, the lexical, syntactic, and semantic violations produced peaks of disruption at the critical word with slightly smaller disruptions one word unit after. Some of the disruptions were significant one or two word units before the critical word as we had obtained in Experiment 13. However, the major differences came from the factual violation. There was a significant disruption from the factual violation in only two conditions, namely, the pronunciation-easy story and the comprehension-difficulty story conditions. In both cases, the factual disruption was significantly different at the critical word. But there was no factual disruption present in the comprehension-easy story condition where we most expected to find one. If the children were disrupted by the factual violation in the easy story with a pronunciation emphasis, they must have been able to process the easy story at all levels of information. That being the case, they surely should have been able to process factual information in the same story when comprehension was emphasized. We have no explanation for this anomaly.

Although there were no obvious differences in the overall pattern of disruptions, a more fine-grained analysis uncovered significant differences in the predicted directions. Since lexical access is necessary for oral production (because articulatory information must be accessed) and also is involved in sentence comprehension, effects at the critical word should reflect differences in both task emphasis and text difficulty. In Figure 31, the average magnitude of disruptions at word units CW and +1 is presented as a function of the violation types. The baseline probability of a disruption is presented on the right. With no violations, there were fewer disruptions with the easy story than with the difficult one, as one would expect. There also were fewer disruptions with the pronunciation emphasis, but only for the easy story. With the difficult

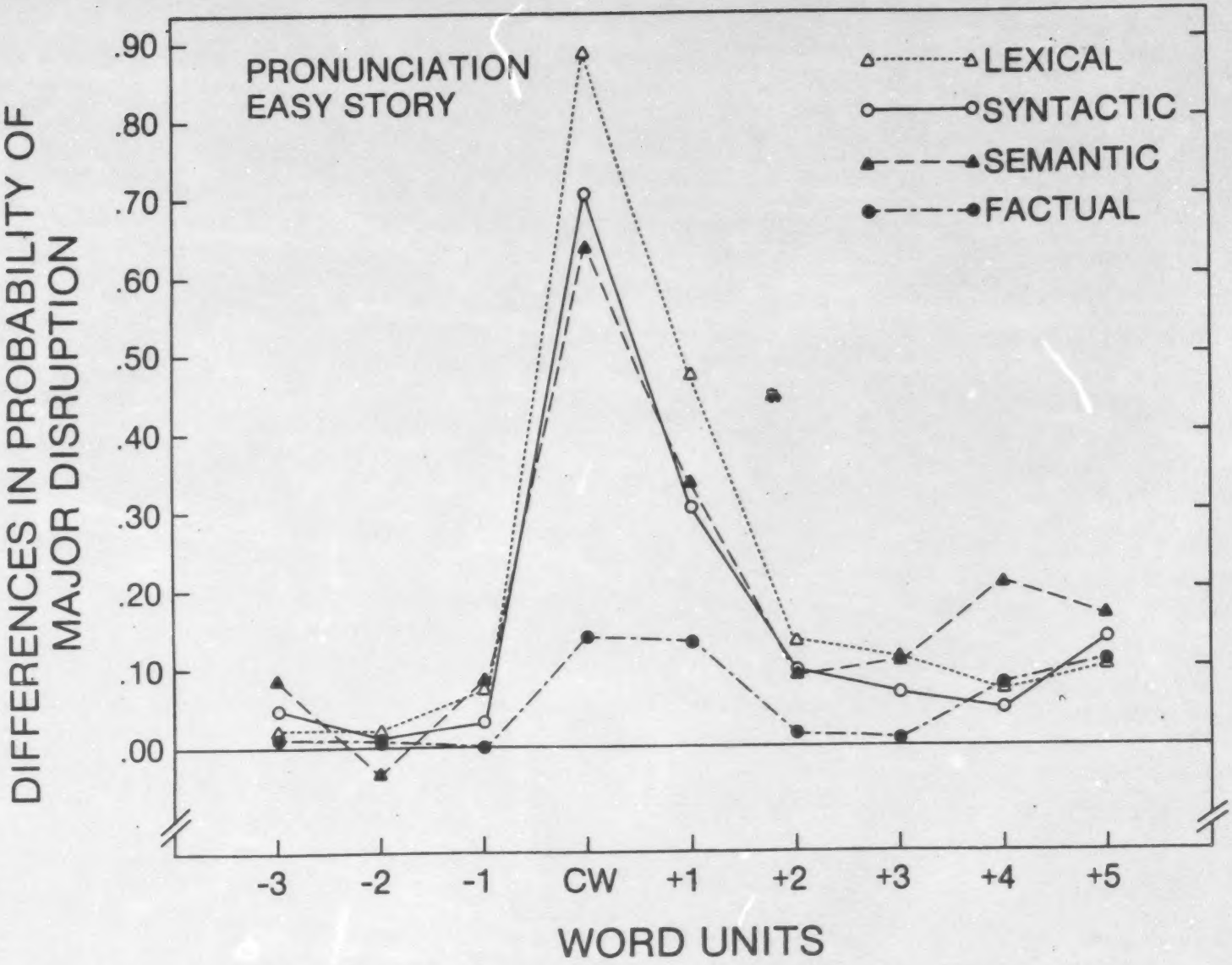

Figure 27. Experiment 16: Second graders' disruption curves for the pronunciation-easy story condition.

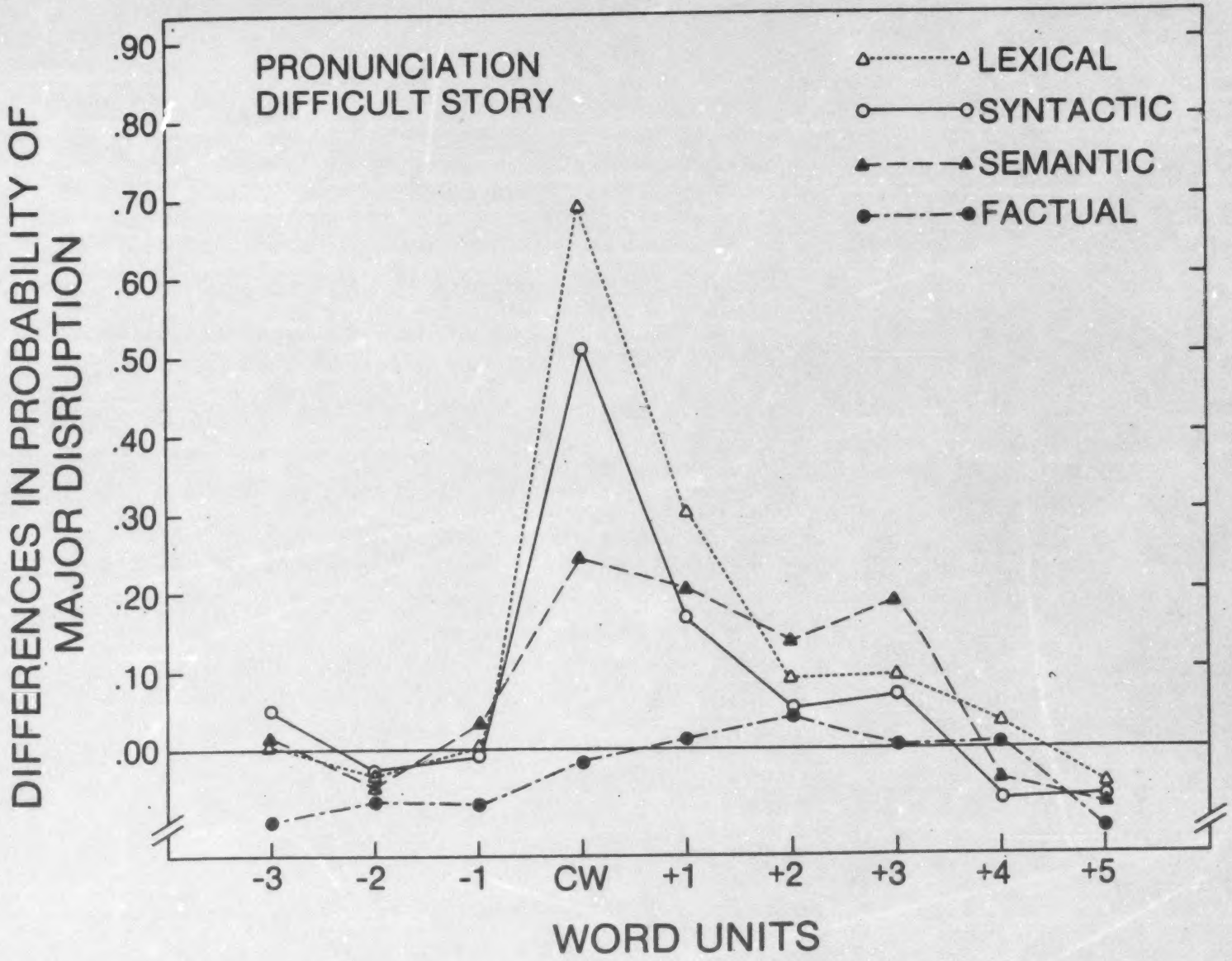

Figure 28. Experiment 16: Second graders' disruption curves for the pronunciation-difficulty story condition.

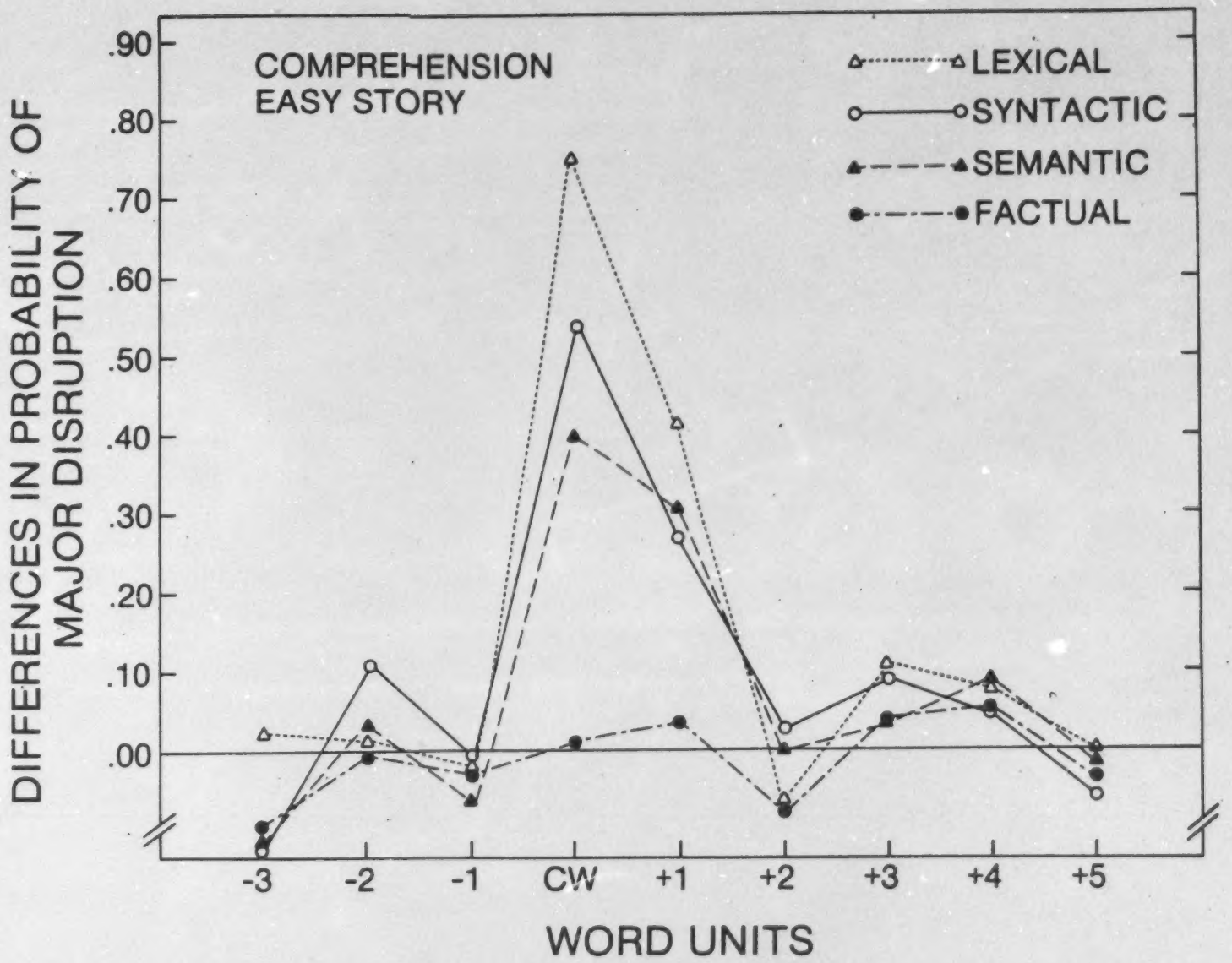

Figure 29. Experiment 16: Second graders' disruption curves for the comprehension-easy story condition.

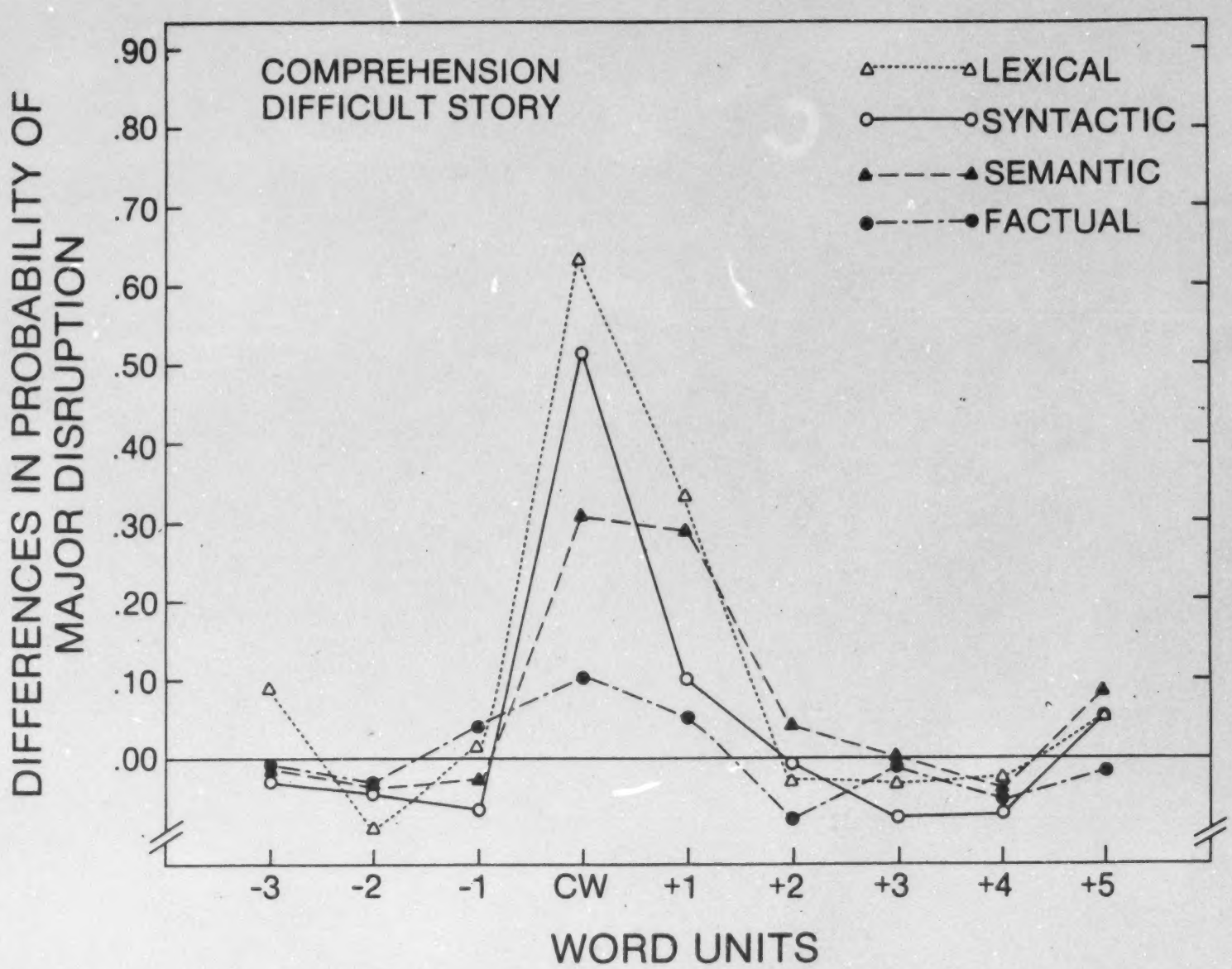

Figure 30. Experiment 16: Second graders' disruption curves for the comprehension-difficult story condition.

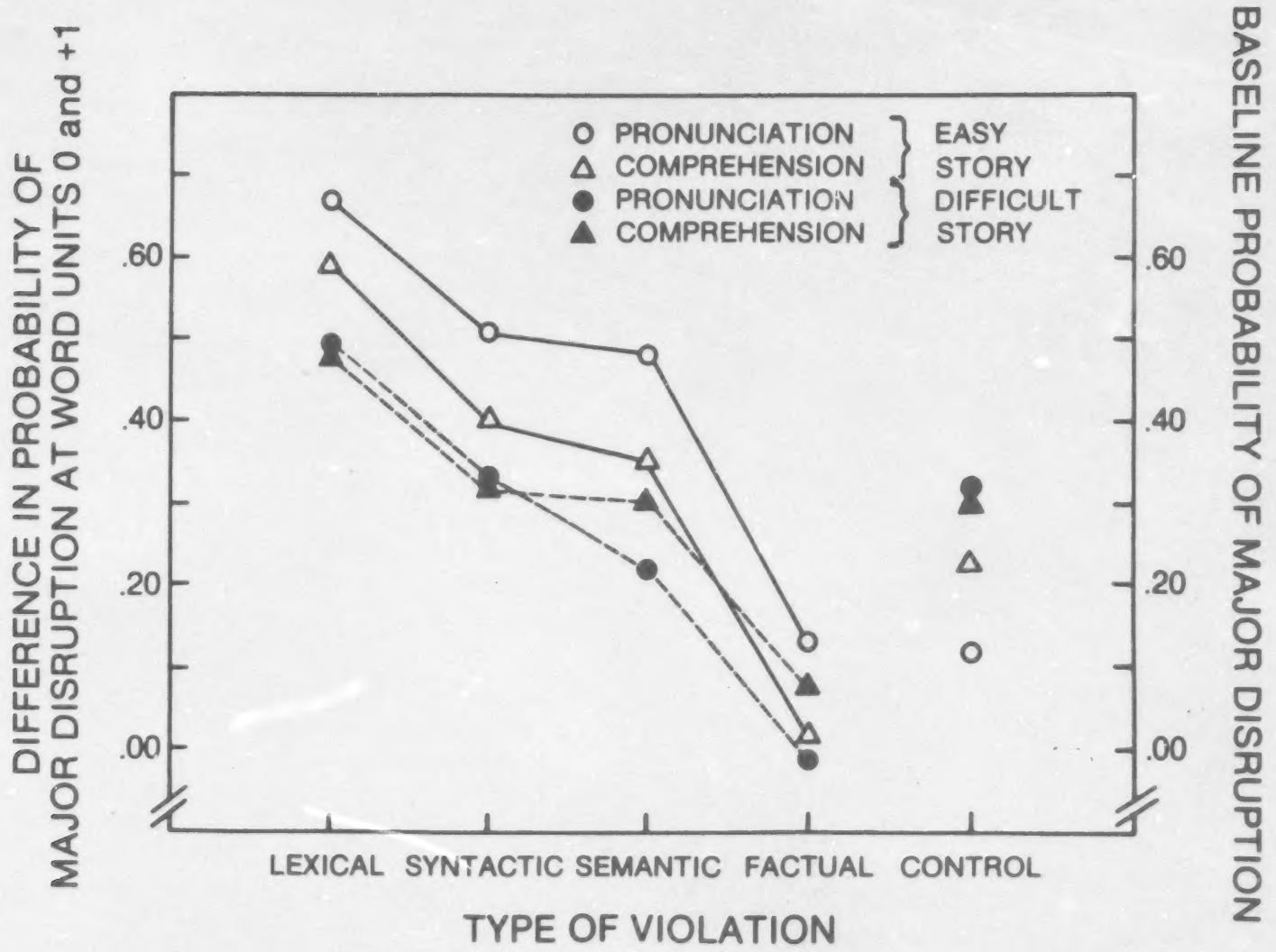

Figure 31. Experiment 16: Magnitudes of disruptions at word units CW and +1 for each condition as a function of violation type.

story, there was virtually no difference between comprehension and pronunciation emphases. These control results support the analysis that, when the story was difficult, readers were less able to vary their processing to meet task emphases.

With respect to the violation conditions, there was a regular decrease in the size of the disruption with increasing abstractness of the information violated--from lexical to syntactic to semantic to factual. With the easy story, the pronunciation and comprehension curves were nearly parallel; the comprehension disruptions were significantly less than the pronunciation disruptions. Why did a comprehension emphasis produce smaller disruptions than a pronunciation emphasis? In the control condition, there were more errors under the comprehension emphasis. But when there was a violation that derailed the lexical access process, the pronunciation group was disrupted more because of the greater emphasis to produce a perfect oral rendition.

With the difficult story, however, there was no difference between the pronunciation and comprehension emphases at the two lower levels of violations--lexical and syntactic--because both groups were near the limits of their abilities to produce an oral production. At the two more abstract levels of violation--semantic and factual--the comprehension group was disrupted more than was the pronunciation group. The pronunciation group plunged ahead being relatively less affected by the semantic and factual violations since that information was less relevant to the pronunciation task. The comprehension group was trying to understand the difficult story, so the semantic and factual violations disrupted that comprehension process. Although these effects were small, they were reliable. These more detailed results, thus, supported the interactive analysis of the reading process.

Restorations of the original critical word when there was a syntactic violation followed a pattern expected from the conceptual analysis of the conditions. With the easy story, a greater percentage of the disruptions were restorations under the comprehension emphasis (41%) than with the pronunciation emphasis (26%). With the pronunciation emphasis, readers were more careful to read what was printed, whereas with the comprehension emphasis, the linguistic context exerted a top-down influence that led the reader to restore the syntactic form of the critical word. In the difficult story, this difference disappeared: the percentage of disruptions that were restorations was virtually the same under the comprehension emphasis (35%) as under the pronunciation emphasis (36%). With the difficult story, readers had to devote more cognitive resources to less abstract types of information so there was less opportunity for the top-down linguistic context to influence lexical access.

In sum, then, with regard to the lexical access and sentence comprehension processes, the effects were consistent with an interactive model of how reading comprehension processes operate. The pronunciation emphasis had its primary effect on lexical access by focusing on the information types that most facilitated producing an oral rendition of the story, namely, lexical and syntactic information. The comprehension emphasis, in contrast, tended to focus relatively more on semantic and factual information that would be used to construct a representation of

the story. The adjustments to processing were not as robust as were those obtained with skilled adult readers, but task-appropriate shifts in processing were evident in the detailed analyses.

In general, we view children as having limited cognitive resources to devote to the tasks implicit in oral reading. In all cases, an oral rendition of the story was required. The task emphases changed the relative amount of cognitive resources allocated to oral production. With an easy story, the oral production task could be satisfied relatively easily leaving some resources for comprehension regardless of task emphasis. A difficult story, in contrast, could not be processed quite so automatically to yield an oral rendition, leaving fewer resources to be applied to comprehension. The distribution of cognitive resources was indexed by the relative sizes, locations, and patterns of the disruptions. The disruptions produced by the violations in the stories differed as a function of the task emphasis and the difficulty level of the story because of the differential demand on and allocation of available cognitive resources (Stanovich, 1980).

The task emphases did not produce as large effects in children as in adults. There are two possible explanations as to why. One is that the task-emphasis manipulations were too short-term to affect the reading process. The children were in the experiment about 30 minutes, so the experimenter had a relatively brief period of time in which to implement the task emphases, in contrast to the hours and hours of classroom instruction. The other side of this explanation is that children simply are not very flexible with their reading strategies. They are unable to vary their reading processes in any appreciable way to meet specific task demands. Their reading processes change, but only with lots of practice and continued instruction. So the short-term manipulations would not have much impact on the ingrained processes that children had acquired through classroom instruction.

A second possible explanation is that the social demands implicit in the experimental situation overwhelmed the specific manipulations. In all conditions, the children's oral reading was examined by an adult. The children were under implicit pressure to perform for the experimenter, just as they perform in many similar situations for the teacher. Performing well in reading implicitly means reading aloud accurately and understanding what is being read. The implicit task has components very similar to the manipulations, but the relative weighting of these subtasks has been set by the classroom teacher's use of oral reading and not by the manipulations. From the children's perspective, then, the task emphases were relatively minor aspects of what the children perceived as an intensive individual examination of their reading skills. Of course, the experimenter was friendly, cordial, and tried to put the children at ease; she tried to emphasize that the experiment was nonevaluative of individuals and the results would not affect their grades. But it seems evident in retrospect that the children still perceived this situation evaluatively, as an examination, despite demurrals to the contrary. So another reason for the lack of robustness of the task-emphasis manipulations in children was that the children's perceptions of the experimental situation was quite different from what we experimenters intended, but perhaps not too different from typical classrooms.

Metacognitive Tasks: Comprehension Monitoring

How do readers recognize that they do not understand what they are reading? One part of successful reading requires that readers monitor their comprehension processes so that they can detect when they do not understand a portion of the text. Without that monitoring, they might "read" every word correctly, but not understand the text as a whole. Whether readers recognize factual inconsistencies in a story provides an opportunity to assess whether readers are monitoring their comprehension. In order for factual inconsistencies to have an effect on oral performance, readers have to recognize that the preceding and critical sentences are not consistent with each other.

The level of awareness at which recognition of comprehension failure occurs and the remedy employed depends on what aspect of the process has been disrupted. In terms of the experimental procedure used here, what type of information has been violated should affect how recognition occurs. For example in Experiment 3, the story was taken from a novel with an abstract, metaphorical style. Additionally, nonconsecutive paragraphs were used which increased the difficulty of forming a macrostructure. Although lexical and syntactic + semantic violations produced striking disruptions, the semantic violation did not (see Figure 6, p. 17). Evidently semantic information was not used in lexical access (contrary to Experiments 1, 2, and 8) and its effect on sentence comprehension was attenuated. The difficult metaphorical story created an expectancy of comprehension failure and so readers were less bothered by semantic violations.

The next two experiments investigated comprehension failure in two metacognitive tasks. The first experiment tested children's recognition of factual inconsistencies using a structured interview. The second experiment evaluated college students' ability to estimate how well they would remember paragraphs that were presented in different organizations.

Experiment 17. Four pairs of short stories (six sentences long) were developed. Two pairs involved a description of a psycholgical trait of a child (e.g., honesty, kindness). An event was then described in which the child responded either consistently or inconsistently with the psychological trait. In two other pairs of stories, an event was described in which an inconsistency in physical states could be inserted (e.g., building a snowman on a hot sandy beach in July). Each reader read four stories--two psychological and two physical, one each consistent and one each inconsistent. Sixty third graders, 60 sixth graders, and 60 college students were tested. One third at each grade level read the stories aloud, one third read them silently, and one third listened while the experimenter read the stories to them. After the stories were presented, each subject was examined with a graded series of questions adapted from Markman (1979) which were designed to elicit whether the subject detected the inconsistency. The interview was arranged in ten steps, ranging from comments made while reading the text to a question as to whether everything made sense to a retelling request to pointing out the inconsistency directly and asking whether it made sense. The primary dependent variable was the step in the interview that the readers gave a clear indication that they recognized the presence of the factual inconsistency.

Only two effects were significant--grade level and type of inconsistency. College students recognized the inconsistency (mean = 2.4) before sixth graders (mean = 3.9) and the sixth graders before the third graders (mean = 5.1). While the differences in grade might reflect differences in comprehension monitoring, they might just as well reflect differential willingness to report the inconsistency. The physical inconsistency was recognized before the psychological (physical mean = 2.7; psychological mean = 4.8). The physical-psychological difference might reflect differences in the "obviousness" of the inconsistency rather than differences inherent in how physical and psychological facts were processed. No other effects or interactions were significant. In particular, the effect of modality of presentation (oral or silent reading or listening) made no difference, nor were there any interactions of type of inconsistency or modality with grade.

To gain additional insight about the grade differences, two "on-line" measures were examined for the reading tasks. The number of major disruptions (as previously defined) was tallied for the oral readers in the inconsistent sentences. Oral and silent reading times were measured for the inconsistent sentences and the sentence immediately before. These scores were compared between stories with inconsistencies and those without (controls). However, for both measures the interaction of consistency with sentence position (i.e., before or after the inconsistent critical sentence) and the interaction of these factors with grade were not significant. So the on-line measures did not support an interpretation that the age differences in the interview point-of-recognition measure were due to differential comprehension monitoring, at least at the time of reading. The on-line measures also failed to replicate the previous findings that factual inconsistencies produced significant increases in major disruptions and production times at all grades (cf. Experiment 13). However, there were a number of differences between Experiment 13 and this one that could account for the failure, such as shorter, simpler stories, on-line measures for the whole sentence and not individual words, and fewer readers tested in each group. In sum, this experiment at best can be considered only a pilot experiment for future investigations into comprehension monitoring. These results by themselves did not paint a sufficiently coherent picture to draw clear conclusions.

Experiment 18. In general, a prerequisite for remembering information is to understand that information; nonsense and distorted information tends to be poorly remembered. In this experiment, college student readers read paragraphs in different sorts of organizations, some of which would facilitate understanding the paragraph as a whole, others of which would interfere with discourse understanding. While reading the paragraphs, they performed one of three rating tasks that were more or less compatable with discourse understanding. Readers then estimated how much of each paragraph they could recall broken down by importance of the ideas. Their actual recall then was matched against their estimations. Reasoning that comprehension and thence recall would be affected by the three factors of orientation task, paragraph organization, and idea importance, would readers monitor their comprehension processes sufficiently accurately so that their estimations of how much they could recall would accurately reflect those factors? Details of this study can be found in Bohn (1982; submitted).

The three orientation tasks were to sort the idea units into three groups either on the basis of fluency, concreteness, or topic relatedness. For materials, three articles on "Windpower," "Television," and "Genetic Research" were adapted from Time magazine. Each article was rewritten as one paragraph of 30 simple idea units. In a preliminary experiment, the 30 idea units were sorted into high, medium, and low categories according to fluency, concreteness, and topic-relatedness criteria. The organization of the paragraphs for the main experiment were based on these ratings. In one organization, the order of the idea units was matched to the orientation instructions and thus were ordered from highest to lowest fluency, concreteness, or topic relatedness, respectively, for each of the three orientation tasks. The second organization was a scrambled random ordering of the idea units. For the third organization, the idea units were ordered in a narrative form as in the original articles.

In each of the nine paragraph organization-orientation task combinations, 50 college students read all three paragraphs. Each group sorted the idea units of each paragraph according to the specific orientation instructions. Then half of each group predicted for each paragraph how many idea units at each level of information (three levels of idea units based on their own sortings) they could recall if asked to do so. Then they actually recalled the paragraphs. The other half of each group first recalled all three paragraphs, then estimated how much they had been able to recall accurately. The dependent measures were the proportion of idea units actually recalled and the proportion estimated recall. The means for these two measures are shown in Table 2.

For recall, orientation task, paragraph organization, and idea-unit level produced significant main effects (see upper half of Table 2). Both concreteness and topic-relatedness orientations produced greater recall than did the more superficial fluency orientation. If concreteness and topic relatedness induced greater depth of processing--concreteness by forcing the reader to relate the ideas to real world referents and topic relatedness by forcing the reader to integrate the idea units with one another--then recall would be better than the more shallow fluency orientation in which the reader needed only to attend to the surface structure of each sentence. The narrative organization produced better recall than did either the scrambled or matched-to-task organizations. This result replicated many findings in the literature that paragraphs that follow canonical narrative structure are understood and thence recalled better than are paragraphs in any other organization (cf. studies reviewed in Danks & Glucksberg, 1980). High level idea units were recalled better than medium level idea units which in turn were recalled better than low level idea units (recall means = .203, .171, and .121, respectively), a result that replicated many findings in the literature that more important ideas are recalled better than less important ones (cf. studies reviewed in Danks & Glucksberg, 1980). The only significant interaction was between orientation task and idea unit level, but it did not affect the interpretation of the main effects. So the assumed effects of task orientation, paragraph organization, and idea-unit level were confirmed in the recall of paragraphs.

To what extent were readers sensitive to these factors when they estimated how much they could recall? Were they monitoring the effects

Table 2

Experiment 18: Mean Proportion of Idea Units Recalled and Mean Proportion Estimated Recall as a Function of Task Orientation and Paragraph Organization

Paragraph Organization	Task Orientation: Fluency	Concreteness	Topic-Relatedness	Mean
		Recalled		
Matched	. .106	.172	.164	.147
Scrambled	.106	.166	.186	.153
Narrative	.143	.231	.213	.196
Mean	.118	.190	.188	
		Estimated		
Matched	.190	.246	.246	.227
Scrambled	.195	.260	.236	.230
Narrative	.237	.277	.278	.264
Mean	.208	.261	.253	

of these factors on their comprehension and could they estimate the effects they would have on their recalls? In general readers were quite accurate, as can be seen by comparing the estimation means (lower half of Table 2) with the recall means. For estimations, the effect of orientation task was significant and the pattern of means was the same as was obtained in recall. The effect of paragraph organization just missed being significant ($p = .053$), but the pattern of estimation means was the same as was obtained in recall. Finally, the estimations for idea-unit levels also followed the means for recall (estimation means = .279, .231, and .211, respectively), a significant effect. The interaction between orientation task and idea-unit level also was significant in estimations, showing the same pattern as in recall, one that did not affect interpretation of the main effects. Whether the readers made their estimations before or after recalling the paragraphs interacted with orientation task and with idea-unit level, but these interactions were rather small deviations that did not affect the overall interpretations.

These results demonstrated quite clearly that readers were sensitive to the same sorts of variables in estimating their recall levels and, by extension, in monitoring their comprehension processes, as affected their actual recall. What cannot be decided is whether readers were sensitive to the differential effects of these factors while they were reading the paragraphs or whether they reconstructed the effects of these factors only when they were asked for their estimations. This issue strikes at the heart of the relation between basic-level cognitive processes, such as comprehension and memory, and meta-level cognitive processes, such as comprehension monitoring and estimation of recallability. Metacognitive processes might be a separate executive process that monitors, evaluates, directs, and controls the basic-level processes. Although such a position is susceptable to attack as initiating an infinite regression of homunculi, it is a position that accords with a computer analogy. An alternative position is that metacognitive processes are not special at all, but are basic-level processes that are activated by a demand for information about other basic-level processes. They meet specific task demands based on the current state of these other processes and the representations present in memory. Considerably more theoretical and empirical research is needed to resolve these issues.

V. Conclusions

Conclusions drawn from the research described in this report are presented in two sections. First, what are the implications for our understanding of the nature of the cognitive processes underlying reading comprehension, specifically for an evaluation of the interactive model proposed in the Introduction? Second, what are the implications of the research for educational practice, especially for the use of oral reading in the classroom?

Theoretical Implications

In general, the results can be interpreted best within the framework of an interactive model. Throughout the experiments the interactive model was refined by specifying more precisely some of the details about how the interaction operates. These experiments have provided information about how different kinds of information interacted in processing components, particularly lexical access and sentence comprehension. The results were quite clear on the necessity for separating information to be processed from the components that process that information. There was no one-to-one mapping between information types and processing components specializing in processing one type of information. A single processing component used several types of information and a given information type was used by more than one component.

Both bottom-up perceptual and top-down contextual information interacted in lexical access. How a lexical violation disrupted lexical access is evident--there was no dictionary entry for the nonword. Physical and spelling information also were used in lexical access although physical violations may have disrupted a perceptual processing component which in turn disrupted lexical access. Spelling violations disrupted lexical access because there was no lexical entry that matched the printed spelling. But there was a similarly spelled word that was pronounced the same as the printed word and which was syntactically and semantically appropriate, so readers could identify the intended word. Syntactic and semantic information also were involved in lexical access. The syntactic and semantic disruptions, especially the semantic, occurred just as soon as and sometimes earlier than did disruptions from violations of less abstract information. The syntactic violation led to fluent restorations of the original critical word indicating a substantial use of top-down information in lexical access. Factual information was not used in lexical access as evidenced by the fact that factual violations never had an effect until after the critical word had been uttered. Although in principle factual information could have influenced lexical access by supplementing syntactic and semantic contextual information, it did not. This lack of effect suggests that lexical access was clausally autonomous, a claim that was not true for sentence comprehension.

In sentence comprehension, there were major disruptions caused by violating syntactic, semantic, and factual information. Disruptions after the critical word had been uttered and before the clause boundary had been reached suggested that sentence comprehension was not clausally autonomous, but proceeded word by word. As each word was accessed, readers attempted to integrate its meaning into a larger representation

of the text without waiting for an entire clause to be received. The syntactic, semantic, and factual violations severely handicapped word-by-word integration. Although there may have been some factual disruption before the clause boundary, factual violations produced their largest disruptions at the clause boundary. Since integration was not possible immediately, readers had to buffer the words until the end of the clause. At that time, the increasing memory load and processing demands forced a final attempt at resolving the violation. The end of a clause was a natural point for readers to resolve any problems they had understanding a sentence. An interactive model of sentence comprehension provides the best account of these results. As words were accessed, each word's meaning was integrated into a global representation of the text. The sentence comprehension component was not autonomous because the global representation spanned more than the immediate sentence.

A central property of interactive models is that there is no canonical reading comprehension process, rather readers adapt it to the specific circumstances. The reading situation can vary in the encoding of information in print, the cognitive skills that readers bring to the task, and the demands that the different tasks impose. All three classes of factors have been shown to affect the reading comprehension process, at least as reflected in the pattern of oral reading disruptions resulting from linguistic violations. Different strategies were devised to resolve the different kinds of information violations. Some of the combination violations produced a disruption pattern different from that produced by single violations, indicating an interaction in how different violations were being handled. Polish readers have developed somewhat different reading strategies from English readers in response to differences in how syntactic information is encoding in Polish and English. Children were differentially flexible to task demands although their processes were quite similar to those of skilled adult readers. When both an oral rendition and comprehension were required, children and adults produced similar patterns of results. But when specific demands were added, e.g., pronunciation and comprehension emphases, children were less flexible than were adults although processing changes were observed in both cases. Whether the story was presented for oral or silent reading or listening influenced processing as reflected in the differential recall of sentences around the critical word. These differences were interpretable by analyzing the cognitive demands imposed by the different modalities. So reading comprehension processes were quite flexible under a variety of situations.

In conclusion, then, an interactive model was supported by the reported results. Although it might be possible to modify an interpretive model to account for each of the results separately, to attempt such modifications for all results would result in an "interpretive" model that looks, walks, and talks like an interactive one. Although the class of possible interactive models has been narrowed somewhat, much more conceptual and empirical work remains to restrict the power of interactive models, and thereby increase their explanatory power.

Implications for Educational Practice

Oral reading is a task frequently used in elementary school classrooms

(Anderson, Shirey, & Mason, 1981; Durkin, 1978-79). It is a convenient tool for instruction and for evaluation because it is a well-defined task. Both children and teachers know what is expected. Unlike silent reading, in which children do not always know whether they have gotten the necessary information, in oral reading if the oral rendition is acceptable, children and their teachers know they have been successful. Comprehension measures, in general, tend to provide more ambiguous and imprecise feedback to both children and teachers.

A real question remains, however, as to what oral reading performance reflects--decoding or comprehension (Danks & Fears, 1979)? The research reported here begins to answer that question, namely, oral reading performance reflects competence and difficulties at all levels of processing. Violations of information sources ranging from physical distortions of the letters to factual inconsistencies between successive sentences lead to disruptions in oral reading performance. What varies is the location of that disruption relative to the violation, and the type of disruptions produced. The difference between the classroom and the laboratory is that the experiments did not wait for processing difficulties to arise spontaneously. Violations were inserted to cause a precisely controlled disruption of the underlying process. If children had difficulty processing any of the information types, it was reflected in their oral reading performance. With spontaneously produced oral reading errors, the source of the difficulty is frequently more difficult to determine. Sometimes the type of oral reading error can be compared with what is printed to determine what information the reader was attending to and what was being ignored (e.g., see the papers in Goodman, 1973a). We would not advocate introducing violations into classroom materials on a regular basis. This research indicated that considerable care should be given to the interpretation of oral reading errors, however, because they do not reflect a difficulty in any single processing component or information source.

Durkin (1978-79) has reported from classroom observations that teachers do not spend much time on reading comprehension in spite of claims to the contrary. With respect to the ubiquitous oral reading task, teachers tend to spend more time and effort correcting pronunciation than stressing comprehension. The experiments on pronunciation and comprehension emphases indicated that such an instructional strategy in the classroom whould lead children to pay more attention to their oral productions and decoding than to understanding the story. While accurate decoding is a desirable skill for development of skilled reading, children should realize that it is only a means to the end of understanding. Over the years, an emphasis on pronunciation could lead to distortions in the reading comprehension process such that children would not be as flexible in adapting to new task demands.

Many teachers tend to correct children's oral renditions even when what is said indicates understanding of the story. Children may utter something other than what is printed either because they cannot decode the print, a real problem to be concerned about, or because they are using multiple sources of information, especially discourse context, to arrive at the correct interpretation. Both sources of information are valid for reading although children should not depend on either one

exclusively lest their reading become too rigid and inflexible. Children's oral renditions also may differ from the print if their oral dialect is different from the one used in the story. They may comprehend the printed story, but their oral production is controlled by their own speech production system. While not addressing the general issue of what to do about dialectal differences in the classroom, it seems clear that these differences in oral renditions are not reading problems. If it is a problem at all, it is a problem of different oral language dialects. To treat it as a reading problem detracts from reading instruction.

Finally, consider the problem of word callers, children who read aloud reasonably fluently but who do not understand what they have read. Goodman has claimed that "remedial reading classes are filled with youngsters in late elementary and secondary schools who can sound out words but get little meaning from their reading" (1973b, p. 491). Other reading specialists claim that the number of true word callers is exceedingly small, that children who are labeled word callers by classroom teachers really have poor decoding skills and/or poor general language comprehension skills. Among the hundreds of elementary school children and college students tested in the experiments reported here, no cases of word calling were uncovered. That is, there were no children who read fluently enough to be tested, but who were not disrupted by syntactic, semantic, and factual violations. Some children and college students were excused from the experiments because they could not read well enough to produce an oral rendition. But all readers who could do that exhibited some understanding. If word callers are as pervasive in schools as claimed by Goodman, it seems surprising that not one was discovered among the hundreds of readers tested. In a small effort to test some word callers, five children referred to the Child Study Center at Kent State University as possible word callers were tested with stories containing semantic and factual violations. All five children showed clear disruptions to both types of violations. No firm conclusions can be drawn from the results to date, but our suspicions have been aroused by the failures so far to find word callers.

In summary, oral reading is not only a useful experimental tool, but it can have instructional value as well. However, its use needs to be carefully evaluated in terms of the effects on the underlying reading process. A better understanding of that process and how oral reading fits into it will permit oral reading to be even more useful in the classroom.

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The bibliography is divided into three sections--publications all or part of which were grant supported, presentations that were grant supported, and other references cited in this report. Publications and presentations marked with an asterisk "*" are reproduced in the Appendix.

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